PROCEEDINGS
OF THE
NATIONAL ACADEMY OF SCIENCES INDIA
1940

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November, 1940

ALLAHABAD

PUBLISHED BY THE COUNCIL

Price Rs. 2 (India) ; Rs. 2/8 (Foreign)

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1940

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PROCEEDINGS

OF THE

NATIONAL ACADEMY OF SCIENCES
INDIA

Part 4] November, 1940 [Volume 10

FORMATION OF PERIODIC PRECIPITATE IN THE ABSENCE OF A FOREIGN GEL, PART V. CERIC HYDROXIDE, CHROMIC HYDROXIDE AND CHROMIC ARSENATE SOLS.

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Communicated by Dr. A. K. Bhattacharya

(Received on July 25, 1940)

SUMMARY

A study has been made of the periodic precipitation of ceric hydroxide, chromic hydroxide and chromic arsenate sols by the process of coagulation, in the absence of a foreign gel. The adsorption of sol by its own precipitate, the nature of the coagula which settle periodically and the speed of coagulation of the sol have been investigated to elucidate the phenomenon.

Ceric Hydroxide Sol

The sol was prepared by subjecting a solution of ceric ammonium-nitrate to hot dialysis. The salt readily hydrolysed in water giving a sol of ceric hydroxide. The parchment paper bag in which the sol was dialysed was changed at intervals due to the digestive action of nitric acid, a product of hydrolysis, on the bag. After 3 hours of hot dialysis the sol was taken out for investigation. It contained 0·1199 g. atom of Ce per litre and its purity was 7·05. It was diluted to 0·05995 g. atom of Ce per litre. The adsorption of sol, the volumes of the coagula and the speed of coagulation of the sol were determined as given in Part II of this series (Mittra, J. Indian Chem. Soc., 1939, **16,** 165).

TABLE I

Sol concentration 0·02995 g. atom of Ce per litre. Sol taken each time 10 c.c. Total volume 20 c.c. of which 9 c.c. contain 0·0002698 g. atom of Ce

Amount of N/40 K_2SO_4	Volume of coagulum	Amount of precipitate peptised
5·5 c.c.	0·25 c.c.	0·000055 g. atom
5·0	0·20	0·000084
4·5	Partial coagulation	

With this concentration and purity of the sol, no rings developed by coagulating with K_2SO_4, as the coagulum yielded was of lyophobic nature. Though the sol could be coagulated with saturated KCl, the preciptating concentration was not within range. Higher concentration of the sol behaved likewise.

Speed of coagulation

The coagulation of the sol with K_2SO_4 was almost instantaneous and hence the speed of coagulation of the sol could not be followed.

Adsorption of sol

TABLE II

Amount of precipitate taken each time 0·592 g. of Ce. Amount of sol taken each time 0·0825 g of Ce

Amount of N/10-K_2SO_4	Amount of Ce left in sol state	% Adsorption
0 c.c.	0·110 g.	−33·94
1	0·107	−29·94
3	0·100	−20·97
5	0·088	− 6·6
7	0·066	20·54
9	0·000	100·00

In the absence of the precipitate, the same amount of the sol required 1·5 c.c. of the electrolyte for complete coagulation.

The original sol was further purified by hot dialysis for 15 hours. It contained 0·1359 g. atom of Ce per litre and its purity was 42·08. It was diluted to 0·05436 g. atom and 0·0408 g. atom of Ce per litre respectively.

TABLE III

Sol concentration 0·05436 g. atom of Ce per litre. Sol taken each time 10 c.c.
Total volume 20 c.c. of which 9 c.c. contain 0·000244 g. atom of Ce

Amount of electrolyte	Volume of coagulum	Amount of precipitate peptised
N/2-KCl		
8 c.c.	0·5 c.c.	0·00010 g. atom
7	0·5	0·00016
6	Partial coagulation	
N/40-K_2SO_4		
7 c.c.	0·5 c.c.	Nothing
6	0·5 c.c.	,,
5	Partial coagulation	

With this concentration and purity of the sol, quite prominent and broad rings developed, by coagulation with KCl (Plate I). The rings were separated by more or less clear spaces. The coagulation with K_2SO_4 was almost instantaneous with no developed rings.

TABLE IV

Sol concentration 0·0408 g. atom of Ce per litre. Sol taken each time 10 c.c.
Total volume 20 c.c. of which 9 c.c. contain 0·000184 g. atom of Ce

Amount of electrolyte	Volume of coagulum	Amount of precipitate peptised
N/2-KCl		
8 c.c.	0·45 c.c.	0·000060 g. atom
7	0·40	0·000098
6	Partial coagulation	
N/40-K_2SO_4		
4 c.c.	0·45 c.c.	Nothing
3	0·45	,,
2	Partial Coagulation	

With this concentration of the sol, quite prominent rings had developed, by coagulation with KCl, but all were broken due to the complete settling of the coagula.

Speed of coagulation

TABLE V

6·8 c.c. of N/2-KCl made upto 10 c.c. coagulated 10 c.c. of the sol in 1 hour (Precipitating concentration)

Time	Amount left in sol state out of 0·000295 g. atom of Ce
After 2 min.	No coagulation
15	0·000284 g. atom
45	0·000200
60	0·000180

Adsorption of sol

TABLE VI

Amount of precipitate taken each time 0·296 g. of Ce. Amount of sol taken each time 0·0936 g. of Ce

Amount of N/2-KCl	Amount of Ce left in sol state	% Adsorption
0 c.c.	0·112 g.	−19·66
1	0·106	−12·82
3	0·090	3·41
5	0·042	55·56
7	0·019	79·48
9	0·000	100·00

In the absence of the precipitate, the same amount of the sol required 20 c.c. of the electrolyte to start the coagulation.

The original sol was further purified by hot dialysis for 15 hours. It contained 0·1603 g. atom of Ce per litre and its purity was 100·21. It was diluted to 0·04809 g. atom of Ce per litre.

TABLE VII

Sol concentration 0·04809 g. atom of Ce per litre Sol taken each time 10 c.c. Total volume 20 c.c. of which 9 c.c. contain 0·000266 g. atom of Ce

Amount of electrolyte	Volume of coagulum	Amount of precipitate peptised
N/2-KCl		
5 − 2 c.c.	0·6 c.c.	Nothing
1	Partial coagulation	
N/40 K_2SO_4		
4 − 2 c.c.	0·5 c.c.	Nothing

With this concentration and purity of the sol, the coagula obtained by coagulating with KCl, were in gel state and no settling occurred even on long standing. The coagulation with K_2SO_4 was almost instantaneous. With lower concentration of the sol rings developed but due to complete settling of the coagula all were broken.

Speed of coagulation

TABLE VIII

2 c.c. of N/2-KCl made upto 10 c.c. coagulated 10 c.c. of the sol in 1 hour (precipitating concentration)

Time	Amount left in sol state out of 0·000295 gm. atom of Ce
After 2 min.	0·000290 g. atom
15	0·000245
45	0·000109
60	0·000000

Adsorption of sol

TABLE IX

Amount of precipitate taken each time 0·296 g of Ce. Amount of sol taken each time 0·1104 g. of Ce

Amount of N/4-KCl	Amount of Ce left in sol state	% Adsorption
0 c.c.	0·1232 g.	−11·60
1	0·1072	2·90
3	0·0832	24·64
5	0·0512	53·62
7	0·0000	100·00

In the absence of the precipitate, the same amount of the sol required 10·5 c.c. of the electrolyte for partial and 13·5 c.c. for complete coagulation.

CHROMIC HYDROXIDE SOL

The sol was prepared by adding ammonium hydroxide to chromic chloride short of precipitation, until the precipitate of chromic hydroxide was peptised with difficulty. The resulting sol was dialysed hot for 30 hours. It contained 0·3368 g. atom of Cr per litre and its purity was 2·26. It was diluted to 0·1684 g atom of Ce per litre.

TABLE X

Sol concentration 0·01684 g. atom of Cr per litre. Sol taken each time 10 c.c. Total volume 20 c.c. of which 9 c c. contain 0·000076 g.atom of Cr

Amount of N/40 K_2SO_4	Volume of coagulum	Amount of precipitate peptised
3·5 c.c.	0·6 c.c.	Nothing
3·0	0·5	"
2·5	Partial coagulation.	

With this concentration of the sol, very few rings, not so well defined, appeared with 3·0 c.c. of the electrolyte. Higher amounts of the electrolyte coagulated the sol instantaneously. Higher concentrations of the sol yielded coagula in gel state with no settling.

Speed of coagulation

TABLE XI

2·5 c.c. of N/10K_2SO_4 coagulated 10 c.c. of the sol in 1 hour (precipitating concentration)

Time	Amount left in sol state out of 0·000295 g. atom of Cr
After 2 min.	0·000162 g. atom
15	0·000084
45	0·000084

Adsorption of sol

TABLE XII

Amount of precipitate taken each time 0·27 g. of Cr. Amount of sol taken each time 0·048 g. of Cr

Amount of N/40K_2SO_4	Amount of Cr left in sol state	% Adsorption
0 c c.	0·057 g.	−18·75
1	0·054	−11·25
3	0·038	20·83
5	0·000	100·00

In the absence of the precipitate, the same amount of the sol required 15 c.c. of the electrolyte to start the coagulation.

The original sol was further purified by hot dialysis for 30 hours. It contained 0·31 g. atom of Cr per litre and its purity was 3·6. It was diluted to 0·0155 g. atom of Cr per litre.

Table XIII

Sol concentration 0·0155 g. atom of Cr per litre. Sol taken each time 10 c.c. Total volume 20 c.c. of which 9 c.c. contain 0·000069 g. atom of Cr

Amount of electrolyte $2N$-KCl	Volume of coagulum	Amount of precipitate peptised
2 c.c. to 3 c.c.	0·4 c.c.	Nothing
1·5 c.c.	Partial coagulation	
$N/100K_2SO_4$		
3·5 c.c. to 4 c.c.	0·4 c.c.	Nothing
3·0 c.c.	Partial coagulation	

With this concentration of the sol, no prominent rings developed with KCl, though slow coagulation occurred. The coagulum in gel state, however got separated in several portions followed by clear spaces, forming gel bands (Plate II) K_2SO_4 coagulated the sol instantaneously with no rings developed.

Speed of coagulation

Table XIV

2·5 c.c. of 2N-KCl (made up to 10 c.c.) coagulated 10 c.c. of the sol in 1 hour (precipitating concentration)

Time	Amount left in sol state out of 0·000295 g. atom of Cr
After 2 min.	No coagulation
15	0·000185 g. atom
45	0·000078
60	Nothing

Adsorption of sol

Amount of precipitate taken each time 0·27 g. of Cr. Amount of sol taken each time 0·085 g. of Cr

Complete adsorption took place in the absence of electrolyte.

Chromic Arsenate Sol

The sol was prepared by adding a solution of acid potassium arsenate to chromic chloride solution and the resulting sol was subjected to cold dialysis for 5 days. It contained 0·3492 g. atom of Cr per litre and its purity was 1·80. It was diluted to 0·0175 g. atom of Cr per litre.

Table XV

Sol concentration 0·0175 g. atom of Cr per litre. Sol taken each time 10 c.c. Total volume 20 c.c. of which 9 c.c. contain 0·0000787 g. atom of Cr

Amount of $N/40K_2SO_4$	Volume of coagulum	Amount of precipitate peptised
2·0 c.c.	0·45 c.c.	Nothing
1·5	0·50	"
1·0	Partial coagulation	

With this concentration of the sol, a few incomplete rings appeared (Plate III). The coagulation with this electrolyte was almost instantaneous. Higher concentrations of the sol yielded coagula in gel state with no settling.

Speed of coagulation

TABLE XVI

4·5 c.c. of $N/40K_2SO_4$ (made up to 10 c.c.) coagulated 10 c.c. of the sol almost instantaneously (precipitating concentration)

Time	Amount left in sol state out of 0·000295 g. atom of Cr
After 2 min.	0·000093 g. atom
„ 15 „	0·000043
30	0·000

The original sol was further purified by cold dialysis for 15 days. It contained 0·3589 g. atom of Cr per litre and its purity was 7·77. It was diluted to several extents and the compact volumes of the coagula were noted by coagulating with 2N-KCl and N/40 K_2SO_4. In each of the cases it was seen that the coagula developed so stiff gels that no settling occurred even on long standing.

There occurred complete adsorption of sol by its own precipitate in the absence of electrolytes.

From the foregoing results it may be seen that periodic precipitation of ceric hydroxide sol is most favourable when the coagulum, obtained from 9 c.c of the total volume of 20 c.c. of the sol-electrolyte mixture, has an optimum volume of 0·5 c.c. on centrifuging. Along with it the speed of coagulation must be slow so as to give a S-shaped character to the coagulation-velocity curve (table V). No rings are obtained with K_2SO_4 as coagulant as the coagulation with this electrolyte is instantaneous, with whatever purity of the sol tried. In the case of chromic hydroxide sol of purity 2·26 the coagulation with K_2SO_4 is not instantaneous (table XI) and there is tendency for the formation of rings, but the speed of coagulation is not slow enough to give rise to the formation of prominent rings. The condition is still more unfavourable with chromic arsenate sol of purity 1·8 When both these chromic hydroxide and chromic arsenate sols are purified to be just coagulated with KCl which produces slow coagulation, the coagula from such sols get so much hydrated that they do not settle at all even on long standing.

The data on the adsorption of sol show that as the sols are purified the adsorption increases with least facility for the formation of rings.

PLATE I

R. N. MITTRA—*Ceric Hydroxide Sol.*

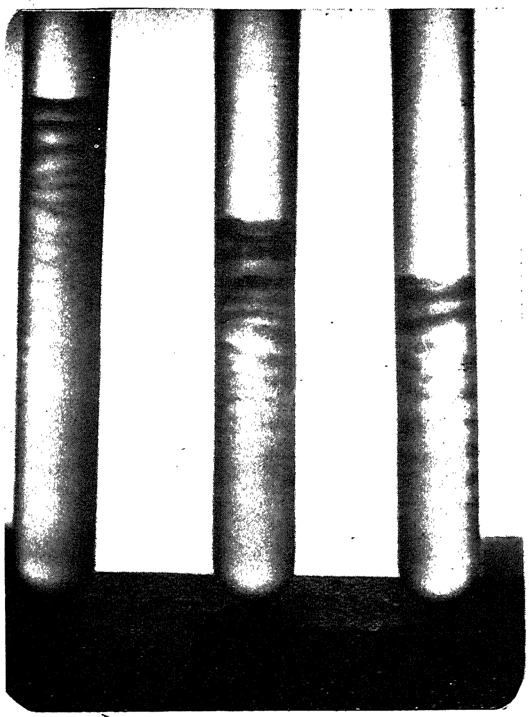
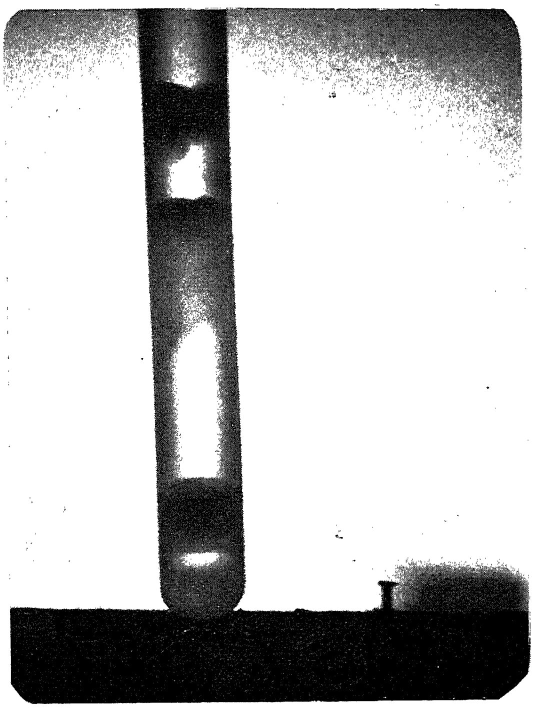


PLATE II

R. N. MITTRA—*Chromic Hydroxide Sol.*



FORMATION OF PERIODIC PRECIPITATE IN THE ABSENCE OF A FOREIGN GEL, PART VI

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Communicated by Dr. A. K. Bhattacharya

(Received on July 25, 1940)

SUMMARY

This paper gives a general condition of the coagula, which can settle periodically, obtained from all the sols studied in this series and discussions on the results obtained.

In previous publications of this series (Mittra, Proc Nat. Acad. Sci., 1936, **6**, 332; 1939, **9**, 131, 138; J. Indian Chem. Soc., 1939, **16**, 165; this issue) it has been reported for the first time by the author that the sols of ferric hydroxide (prepared by acetate and carbonate methods), ferric phosphate, ferric arsenate, ferric borate, ceric hydroxide, chromic hydroxide, chromic arsenate, give rise to periodicity in their coagula when they are subjected to slow coagulation by the addition of mono or bivalent electrolytes according to their respective nature and purity. The formation of periodic precipitates of insoluble substances by the interaction of two solutes in gel medium recalls the investigation of Liesegang in 1896. Large amounts of similar observations were made in recent years by several workers (Bradford, Bio. Chemical Journal, 1921, **15**, 554; 1916, **10**, 169; Science Progress, 1916, **10**, 369. Dhar and Chatterji, Kolloid Z., 1922, **31**, 15; 1925, **37**, 2; 1926, **40**, 97. Hedges and Henley, Jour. Chem. Soc., 1928, 2714). Periodicities in sparingly soluble substances without the presence of a gel have also been reported by some workers, (Fischer and Schmidt, Rocz. Chem., 1926, **6**, 404. Capisarow, Jour. Chem. Soc., 1927, 222. Morse, J. Phys. Chem., 1930, **34**, 1554) when a reacting solution diffuses into the other held in capillary spaces or tubes.

The formation of periodic precipitates investigated by the above workers depend primarily on the formation of a sparingly soluble substance obtained by a preceding chemical reaction. It should, clearly, be stated that in the production of rings by a general double decomposition method in a gel medium, there are three stages which guide the phenomenon: (1) formation of an insoluble substance by the chemical interaction between two reacting solutes, (2) aggregation of the insoluble substance to form colloidal aggregates, and finally (3) the precipitation of the colloidal material in a periodic manner. The first stage of the process has been considered as no less an important factor for the production of rings by Wo Ostwald (Kolloid Z., 1926, **40**, 144). He attributes the formation of periodic

structures to the chemical interaction occurring between two reacting solutes in a gel medium, in waves. The points of interference of such wave-like motions of the reacting agents and also of the third product of the reaction have been supposed to be the nodes where the insoluble substance gets precipitated giving rise to periodic structures.

With the simple process carried on by the author in obtaining the periodic precipitates, the first stage of the process has completely been eliminated. That is, no preceding chemical reaction is necessary for the production of the insoluble substance which already exists in the colloidal condition.

The sol of partially lyophilic nature are prepared at different stages of purity. 10 c.c. portion of these sols are mixed with different electrolytes in separate test tubes, the total volumes being made up to 20 c.c. The tubes are kept for 24 hours for slow coagulation. From the results on the sols studied in this series it has been shown that an optimum volume of the coagula is necessary for their settling periodically. When 9 c.c. of the suspension obtained on thorough shaking of the coagula which has settled periodically, out of the total volume of 20 c.c. of the sol-electrolyte mixture, are centrifuged for 5 minutes, at a revolution of 2000 r. p.m. the compact volume of the coagulum is 0·5 c c. But with increase in purity of the sol the coagulum gets more hydrous and does not settle in a periodic manner, inspite of maintaining the concentration of the sol such that the optimum volume is reached. Thus in order to make out a general condition of all the sols which can guide the formation of rings, a comparative study of the sols have been found necessary. Along with the study already made the sols were maintained at the same concentration of 0·07378g. atom of the metal, constituting the sol, per litre. 10 c.c. of the sol were coagulated by different concentrations of electrolytes and the total volumes were made up to 20 c.c. After an hour the content of the tube, in which coagulation has just occurred, was shaken thoroughly and 8 c.c.f rom it with a metal content of 0·000295g. atom were subjected to centrifuge at a speed of 2000 r. p. m. for 5 minutes. The compact volume of the coagulum was noted. The following are the results obtained with different sols studied in this series.

Purity.	Volume of coagulum (with KCl).	Volume of coagulum (with K_2SO_4).
	Ferric hydroxide sol (acetate).	
0·57	0·45 c.c.	...
2·06	1·0*	...
6·66	1·3	...
	Ferric hydroxide sol (carbonate).	
1·12	...	0·9 c.c.
4·93	1·0*	...
8·62	1·3	...

	Ferric hydroxide sol (Krecke's).	
21·70	0·15	...
120·60	0·25	...
	Ferric phosphate sol.	
0·50	...	1·0*
1·14	...	1·0
1·92	...	1·2
	Ferric borate sol.	
1·24	...	1·0*
2·78	...	1·2
5·62	...	1·4
	Ceric hydroxide sol.	
7·05	...	0·3
42·08	1·0*	...
100·21	1·3	...
	Chromic hydroxide sol.	
2·26	..	1·1
5·87	3·5	2·2
	Chromic arsenate sol.	
1·80	...	1·4

From the above table it is seen that the sols are best suited for the production of rings the coagula from which containing 0·000295g. atom of the metal constituting the sol, occupy a compact volume of 1·0 c.c. Along with it the speed of coagulation either with mono or bivalent coagulating ions must be slow. It will be of interest to note here that in some cases bivalent coagulating ions produce slow coagulation but with very impure sols. It appears that the charge neutralisation by monovalent coagulating ions generally and by bivalent ions only in impure sols is a slow process and this is due to the presence of a large amount of the stablishing ions in the sols. It is probable that during such a process of slow coagulation, the electric charge on the colloid particles may not diminish to the extent of minimum potential. The adsorption of the electrically charged particles by the precipitated material obtained by the partial coagulation of the sol, may take down the whole of the dispersed material and the sol thus gets completely coagulated. This may also be seen from data on the rate of coagulation. The coagulation proceeds at first

* The asterisks *indicate the volume where best rings develop.

very slowly and then rises quickly and finally falls off towards the completion of the process. The velocity-coagulation curves are therefore S-shaped. This autocatalytic nature of the curves can only be explained by the adsorption of the uncoagulated sol by the coagulum already appeared, and this adsorption increases enormously with more of the coagulum appearing. It has generally been observed that when the coagulum, obtained from a sol coagulated completely by a minimum quantity of electrolyte, is shaken and centrifuged it leaves some of it in sol state, and the amount of coagulum thus peptised is in most cases comparatively larger when the coagulation is effected by monovalent electrolytes. This evinces that some of the colloid particles are mechanically carried down by the partially coagulated material. In the case of purer sols, the charge neutralisation of the colloid particles is more or less complete. This leads to greater aggregation of the particles and very little or no precipitate is peptised while centrifuging. Thus adsorption plays an important role along with slow coagulation in the process of ring formation. When partially purified sol is subjected to slow coagulation, the coagula which appear in stages have the facility for co-existing with the uncoagulated sol and form adsorption centres where the first set of nuclei started. With time the adsorption centres get thickened up by adsorbing more sol and form uniform bands in the shape of rings. This process of adsorption is further facilitated by the slight settling of the coagula. The rings are held up in position due to the hydrous condition of the medium.

If the purification of the sol be carried on too far, the range of slow coagulation shortens considerably and the coagulation velocity curve is not S-shaped but takes an asymptotic nature. The coagulum also gets more hydrous and its compact volume containing 0·000295 g. atom of the metal goes beyond 1·0 c.c. No rings are obtained at this stage though maximum adsorption takes place of the sol by its own precipitate. This may also be seen from the experiments that the amount of precipitate getting peptised on centrifuging decreases considerably with increase in purity of the sol. That is, the loosely adsorbed sol by the precipitated mass gets more firmly adsorbed on purification. The adsorption experiments carried on during the study also show that the adsorption of sol by its own precipitate goes on increasing with increase in purity of the sol, where the facility for ring formation is the least. Thus adsorption of sol by its own precipitate is a general phenomenon in colloids and is not a criterion in the process of ring formation. Any sol will give rise to periodicity in its coagulum which satisfies the two factors : (1) the speed of coagulation and (2) the nature of coagulum.

In conclusion, the author wishes to express his indebtedness to the authorities of the University of Allahabad for granting him the D. Sc. Research Scholarship for the period the work was being carried on.

PHYSIOLOGICAL STUDIES ON THE WHEAT PLANT. PART III THE CHLOROPHYLL AND CARBOHYDRATE CONTENTS OF *TRITICUM VULGARE* IN RELATION TO MANURES

By Gopi Narain Dikshit and Shri Ranjan

Botany Department, University of Allahabad.

(Received on January 14, 1940.)

SUMMARY

The quantities of all the four pigments show wide fluctuations during the ontogenic drift of the Wheat plant. These fluctuations are noticed in plants growing in the Subsoil, Molasses, Compost and Control beds.

The monosaccharides are the highest in the young stage and rapidly decline off as the age of plants advanced. The disaccharides, however, show a maximum concentration when the life cycle of the plant is half completed

There is no definite correlation between the plant pigments and the soluble carbohydrates. This proves that the pigments under the given experimental conditions are above the limiting value.

Introduction

In a previous paper on Wheat[10], from this laboratory, the investigation was undertaken with a view to establish a correlation, in any, with amino and total nitrogen and the yield.

In continuing the work on Wheat, in the present paper, we have attempted to correlate the carbohydrate and chlorophyll contents of plants in relation to different soils.

Willstätter and Stoll[15] in their discussion on the relation of the chlorophyll content to photosynthetic rate showed :—

(1) that chlorophyll does not change during photosynthesis,

(2) ratio of chlorophyll A and B and that of the yellow pigments remains nearly constant during photosynthesis,

(3) and that with an increase of chlorophyll content there is also an increase in photosynthesis. There is, however, not a direct proportionality between the two, and the two are by no means parallel.

So far as we know, no work of any importance has been done on the ratio of the formation of the pigments to the manurial content of the soil, also no definite correlation has been established between the salts of the soil, the chlorophyll and the carbohydrates of the leaves.

We have attempted here to show whether any correlation exists between soil factor, chlorophyll and the sugars of the leaves, and their final yield.

MATERIAL AND METHOD

(*a*) *Seeds.*—Pusa no. 52 strain was sown in the Botanical Gardens, University of Allahabad, by the broadcast method on October 15, 1938. A few seedlings were also germinated in the Sawdust. The first experiments on wheat were carried out when the plants were 6 to 11 days old.

(*b*) *Estimation of sugars.*—Sugars were determined by Benedict's[6] and Dastur and Samant's[4] methods.

For determining the sugars, about 2—5 gms. of leaves were taken and immediately killed by putting in boiling water and boiled for about 2—3 minutes. They were then crushed into a paste with a little sand in a hand mortar. A pinch of basic Lead Acetate was then added. The leaf extract was then decanted and filtered through a Suction filter and a slow current of sulphuretted hydrogen was passed through in order to precipitate completely the insoluble black Lead sulphide. The solution was filtered again. The volatile H_2S was driven out and the solutions were then concentrated to a given volume. They were then divided into two parts, one of which was used for estimating the monosaccharides and the other for the disaccharides.

Dastur and Samant's[4] method of phosphomolybdic acid was also tried. They used two standard solutions.

(*a*) $CuSO_4$ solution containing Na_2CO_3 and tartaric acid is kept in the dark in a coloured bottle,

(*b*) Phosphomolybdic acid solution.

According to them 2 c.c. of solution "B" would render 2 c.c. of solution "A" colourless. We, however, failed to get such a result and found that even the addition of 4—5 c c of "B" to 2 c.c. of "A" would not completely render the solution colourless, a slight bluish-green tinge would remain persistent.

This blue colour was then matched with the blue colour of the standard solution with the Duboscq-Colorimeter after 40 minutes of the production of the blue colour.

Standard Sugar Solution.—consisted of 0·002% of anhydrous glucose solution, in which a little toluene was added.

We attempted the tartaric acid method of the hydrolysis of the disaccharides as suggested by Dastur and Samant, but found that hydrochloric acid gave more satisfactory results.

In Benedict's solution for the estimation of reducing sugars, the difficulty of the red precipitate of Cuprous Oxide, obscuring the end point is overcome by carrying out the reduction in the presence of KCNS, whereby the Cuprous Oxide is converted into an insoluble white compound and thus the disappearance of the last trace of blue colour from the solution is ready to observe.

1 c c. of Benedict's solution $=0 \cdot 002$ gms. of glucose.

As Benedict's solution gave us better results, in our later experiments we have followed this method,

(c) *The quantitative estimations of the pigments*:—The chlorophyll determinations were carried out by the help of the Hellige-Duboscq-Colorimeter with the use of the Inorganic standard solutions, given as follows according to Guthrie[5] :—

(1) 11·40 gms. of pure Copper sulphate dissolved in water and the solution made to one litre,

(2) 20 gms. of recrystallised $K_2Cr_2O_7$ dissolved in water and solution made to one litre,

(3) 2M solution of ammonia (mol. wt. 35·05) with the help of a hydrometer.

The colour standard was prepared by mixing 25 c.c. of Cu_2SO_4 soln. and 50 c.c. of $K_2Cr_2O_7$ and 10 c.c. of ammonia and making to 100 c.c. in a measuring flask.

Standard solution for yellow pigments.—2 gms. of recrystallised Potassium bichromate were dissolved in water and the solution made to one litre.

25 c.c. of this were made up-to one hundred c.c. for the standard.

Procedure.—1 gm. of fresh green leaf was accurately weighed and finely crushed with a little washed sand and washed with 35% acetone repeatedly over a Büchner funnel until the filtrate was colourless. This dirty brown acetone solution was rejected. The dry residue over the Büchner funnel was next treated with pure acetone repeatedly to extract all the chlorophyll pigments (until the filtrate was absolutely colourless). To this about 10 c c of water and ether-petroli about twice the volume of acetone was added in a separating funnel, and acetone washed with water several times to remove all the traces of acetone. The ethereal solution of the leaf pigments was then saponified with 30% KOH in methyl alcohol, in the cold, and two layers were formed, the upper one brilliant green containing the green pigments A and B, and the lower one transparent pale yellow containing Carotin and Xanthophyll. The green pigments brought to a volume of 25 c.c. were next matched with Guthrie's green, previously prepared, with the Hellige-Duboscq Colorimeter.

Separation of Carotin and Xanthophyll.—The ethereal solution of Carotin and Xanthophyll was washed carefully with distilled water and evaporated to dryness and then about 35 c.c. of petroleum ether and 15 c.c. of 85% methyl alcohol was added to it, in a separating funnel. The lower layer of Xanthophyll was run off in another separating funnel and freed from any Carotin by adding a few c.c. of petroleum ether. The upper layer contained Carotin. In some cases when the extract were cloudy a few drops only of absolute alcohol, were added to clear.

Experimental Results

The examination of the chlorophylls were taken in the manner given above. From Fig. 1 it is evident that the variation of the quantities of chlorophyll at

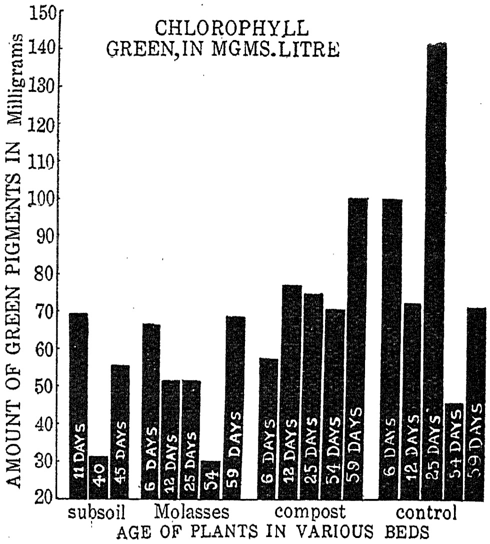

Fig. 1

different ages of the plants in the various soils does not follow any uniform principle, and therefore broad generalizations can only be made. Generally speaking, we may say that the chlorophyll of plants growing in the Subsoil and Molasses beds are less than the chlorophyll plants in the Compost and Control beds.

Carotin and Xanthophyll

While it was difficult to deduce the chlorophyll content of plants in various beds to a given scheme, it has been more difficult to bring the Carotin and Xanthophyll concentrations of plants to any uniform system.

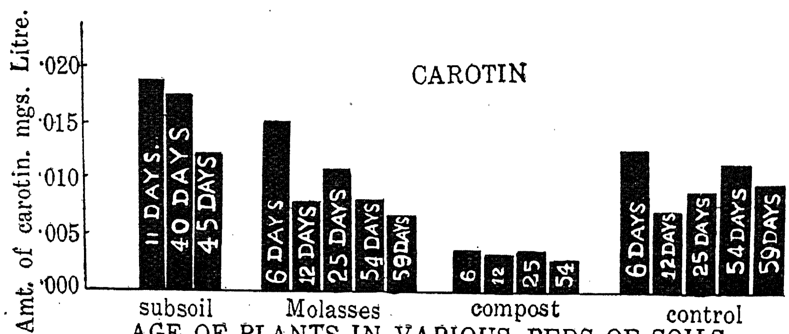

Fig. 2

Fig. 2 for Carotin shows that the amount of this pigment in plants growing in the Compost beds was small, while the contents of Carotin in the Control, Molasses and Subsoil seem to be pretty nearly the same.

Xanthophyll, on the other hand (Fig. 3), seems to be in general the same in plants growing in the various beds.

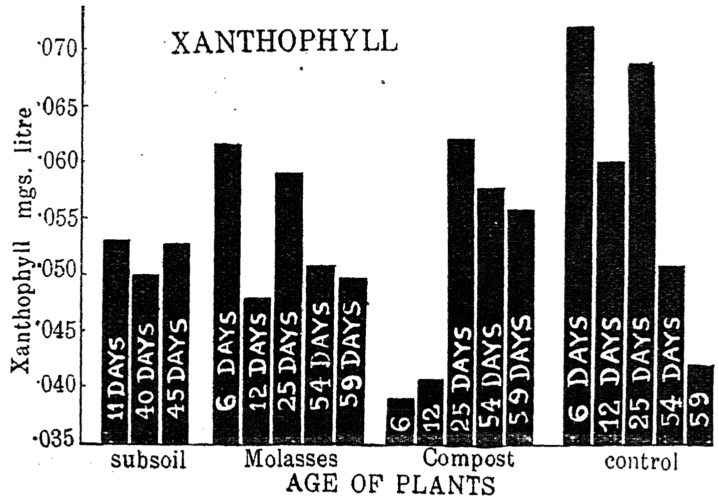

Fig. 3

Fig. 3 shows the development of Xanthophyll pigments in various soils.

Monosaccharides and Disaccharides.—Fig. 4 and 5 for the monosaccharides and the disaccharides are slightly more regular. In practically all cases, the values of the monosaccharides are very high for plants 6 days old. This value then rapidly falls and then keeps to a fluctuating low level.

In the case of the disaccharides (Fig. 5) the curves seem to be of a more or less binomial type. Here the values at both the start and end of experiments is each low, while invariably the highest peak is reached when the life cycle of the plant is half completed.

Yield of grain and straw per seed sown.—During the month of March, when the ear ripened, the plants growing from one seed sown were carefully removed by the randomisation method from each of the beds. All the ears were removed from the straw in each plant, they were put in a drying oven and dried at 95°C and their dry weights then taken. The results are as follows :—

Beds.	Grains in grams.	Straw in grams.
Compost	1·825	2·409
Control	1·782	2·21
Molasses	1·612	1·98
Subsoil	1·320	1·177

DISCUSSION OF THE RESULTS

The relation of plant pigments to the soluble carbohydrate in the leaf.—According to Willstätter and Stoll, the chlorophylls in certain cases influence the rate of

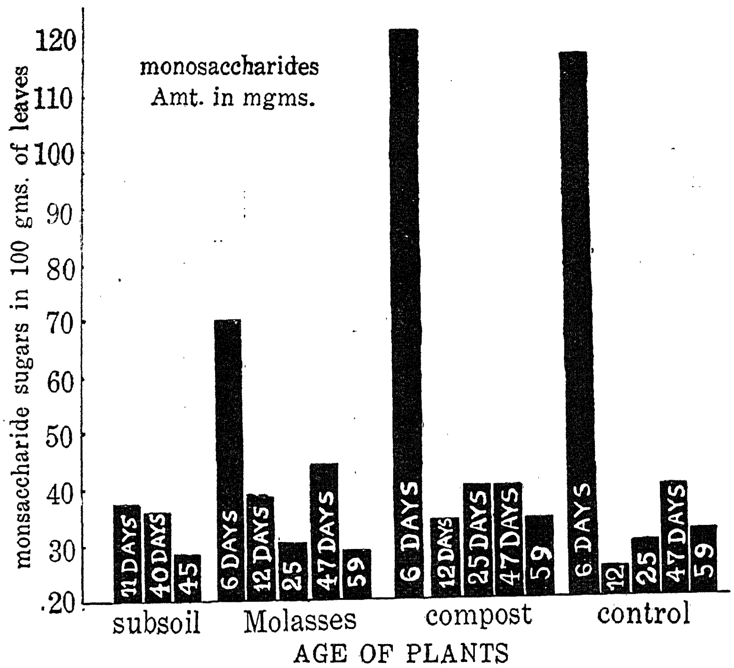

Fig. 4

photosynthesis. Our results here, strictly speaking, do not give us any very clear ideas on this subject for we could not take into account the other metabolites formed as a result of photosynthesis, except the mono and disaccharides. We confess, our data is rather meagre, but from what little evidence we have, no close correlation can be established. Taking the case of the monosaccharides, we get the highest value as is natural, in the very young stage, when the chlorophyll content was relatively low. The monosaccharides then fall without any relation to the chlorophylls present in the leaves. Then again the case of the disaccharides is so different from the monosaccharides and bears no relation with either the monosaccharides or the chlorophyll contents, see Figs. 1, 4, and 5.

The relation between the Hydrocarbon pigments and the soluble carbohydrates are also non-existent, for whereas in the case of Carotin, the pigment is the least in plants growing in the Compost bed, the quantity of both the mono and disaccharides is by no means small.

We are thus lead to believe that in all the beds (Subsoil, Molasses, Compost and Control) there was ample provision for the development of pigments in plants, and these pigments were above the limiting value under the given experimental conditions. Thus the slight variations of these pigments had no effect on the actual formation of the metabolites during photosynthesis.

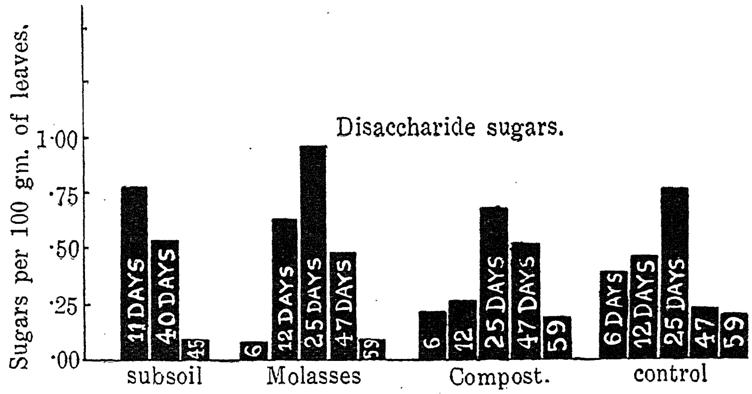

Fig. 5

Total yield in relation to the various soils.—Though no relation could be established between the pigments per given weight of plants and the soluble carbohydrates, yet it is abundantly clear that there has been wide differences in the yield of the crop in the various beds.

It was noticed that far more tillers appeared in the case of plants growing in the Compost than what was found in the Molasses or Subsoil beds. Thus the total reactive surface was far greater in the Compost bed which was thus responsible in giving greater yield of the total quantity of the grain. An attempt will be made in the next paper, following this, as to account for the causes responsible for the greater production of these as tillers, but we may safely conclude here, that so far as the chlorophyll content was concerned, it was present in adequate quantities to allow an optimum photosynthetic activity per given weight of the plant material.

APPENDIX 1

Age of plants in days.	Plot.	In milligrams per litre.			In grams per 100 gm. of fresh leaves.	
		Chlorophyll	Xanthophyll	Carotin	Monosaccharides	Di-Sugars
8	Sawdust ...	50·2	0·054	0·018	2·0	0·50
6	Molasses ...	67·0	0·062	0·0152	1·2	0·07
	Compost ...	57·0	0·039	0·0046	2·5	0·2
	Control ...	100·7	0·0724	0·0130	2·24	0·39
14	Sawdust ...	30·5	0·052	0·027	0·75	0·14
12	Molasses ..	51·9	0·048	0·008	0·47	0·63
	Compost ...	60·3	0·041	0·0036	0·36	0·29
	Control ...	72·6	0·0615	0·0078	0·14	0·46
25	Molasses ...	51·9	0·059	0·011	0·20	0·90
	Compost ...	77·7	0·062	0·0041	0·50	0·68
	Control ...	144·0	0·069	0·009	0·25	0·78
11	Subsoil ...	69·0	0·0537	0·0189	0·44	0·79
47	Molasses ...	...	...	...	0·60	0 47
	Compost ...	...	...	...	0·51	0·56
	Control ...	...	...	...	0·47	0·255
54	Molasses ...	30·0	0·051	0·0082	...	...
	Compost ...	75·4	0·058	0·0[illegible]3	...	...
	Control ...	44·7	0·051	0·012	...	...
40	Subsoil ...	32·2	0·049	0·0174	0 39	0·56
59	Molasses ...	69·	0·047	0·007	0·21 (V. few ears were developed).	0·05
	Compost ...	70·8	0·056	0·0032	0·36 in Leaf 2·06 in ears	0·18 in Leaf 0·94 in ears
	Control ...	72·0	0·042	0·0107	0·317 (Leaf) 1·87 (ears)	0·2 (Leaf) 0·87 (ears)
45	Subsoil ...	55·0	0·053	0·0137	0·20	0·07

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A NEW DISTOME *ENTEROHAEMATOTREMA* N.G. AND A NEW BLOOD FLUKE *HEMIORCHIS BENGALENSIS* N.SP. BELONGING TO THE FAMILY SPIRORCHIDÆ STUNKARD, AND A NEW SPECIES OF THE GENUS *DENDRITOBILHARZIA* SKRJABIN AND ZAKHAROW BELONGING TO THE FAMILY SCHISTOSOMATIDÆ POCHE, WITH REMARKS ON THE EVOLUTION OF THE BLOOD FLUKES

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(Received on April 6, 1940)

SUMMARY

A new genus ***Enterohæmatotrema*** belonging to the family Spirorchidæ from the intestine of a fresh water turtle is described and its affinities discussed.

The diagnosis of the genus ***Hemiorchis*** Mehra with an account of its two species is given. A new species of the little known genus ***Dendritobilharzia*** is described and two new subfamilies Dendritobilharzinæ and Gigantobilharzinæ are created.

A discussion on the evolution of the blood flukes is given.

The new genus *Enterohæmatotrema* described in this paper shows unmistakably close affinities with the blood flukes of the genus *Coeuritrema* Mehra, and represents the probable intestinal distome ancestor from which the blood flukes have been evolved. It falls into the group of the two genera of the subfamily Hapalotreminæ, *Cœuritrema* Mehra and *Hapalorhynchus* Stunkard which are characterised by the presence of the two testes with the ovary between them. Byrd (1939) in his revision of the family Spirorchidæ follows Price in considering these genera as synonymous, but as already discussed by us (1939) we do not agree with this view, and the account of the three new species of *Hapalorhynchus* described by Byrd (1939) confirms our opinion. *Enterohæmatotrema* n.g., is distinguished from *Coeuritrema* by the median pre-equatorial position of the genital opening on ventral side of the body immediately behind the acetabulum, shape and position of the cirrus sac and metraterm and the habitat in the gut instead of the vascular system of the turtle.

The view advocated by Byrd (1939) that the family Spirorchidæ should be considered as a unit and be not divided into subfamilies does not commend to us. Our system of classification is essentially based on the central idea of relationships displayed by the various subdivisions into which a group may be conveniently

divided with or without intergradations. If we can delimit the various subfamilies of the Spirorchidæ on the basis of fairly deep-seated and constant characters, irrespective of the intermediate characters displayed by some of the genera, there is no reason why this classification which is essentially meant for the convenience of workers on the group should not be adopted.

Byrd mainly on the basis of the reasons given by Stunkard in 1923 expresses his agreement with the latter author's view that the Spirorchidæ are the descendants of the more primitive Aporocotylidæ through the genus *Aporocotyle*. This view was fully discussed and refuted by us in 1933, and the converse view was put forward that the Aprocotylidæ and the more degenerate Sanguinicolidæ are the suckerless descendants of the Spirorchidæ. The phylogenetic scheme given by Byrd showing the probable relationship among the various genera of the Spirorchidæ is retrograde and untenable in view of our above-mentioned discussion, and this is confirmed now by the discovery of *Enterohæmatotrema* n.g., which while possessing Cœuritrema-Hapalorhynchus type of morphology is an intestinal and not a blood parasite of its host.

It is strange that Byrd considers *Plasmiorchis* to be synonymous with *Spirorchis*. The presence of a ventral sucker and the forwardly directed loops at the origin of the cæca are such constant features of the former genus so as to sharply separate it from the latter. *Hemiorchis bengalensis* n.sp. described in the paper confirms the validity of the genus *Hemiorchis* Mehra, 1939 created for *Plasmiorchis hardellii*.

A new species of the little known genus *Dendritobilharzia* from *Nettion crecca crecca* is described. The genera *Dendritobilharzia* and *Gigantobilharzia* are removed from the subfamily Bilharziellinæ to the two new subfamilies created for them, *i.e.*, the Dendritobilharzinæ and Gigantobilharzinæ respectively.

The genus *Chinhuta* Lal is dropped and its species is assigned to *Bilharziella* under the name *Bilharziella indica* (Lal, 1937).

Family Spirorchidæ Stunkard.

Subfamily Hapalotreminæ Stunkard.

Enterohæmatotrema nov. gen.

Generic diagnosis. Spirorchidæ. Hapalotreminæ Minute, slender, delicate, elongated distomes; cuticle entirely devoid of spines or verrucæ. Oral sucker oval, somewhat cup-shaped, and protrusible; ventral sucker present at about one third body length from anterior end. Pharynx absent; œsophagus long and sinuous with two or three bends and surrounded by gland cells; œsophageal vesicle at intestinal bifurcation absent; intestinal cæca lateral, covered by vetellarian follicles behind genital opening and undulating behind posterior testis, terminating a short distance

in front of hinder end. Genital opening median, ventral, immediately behind ventral sucker and much in front of the middle of body length. Testes two in number with ovary between them, entire, subspherical or ovoid, situated in posterior half of body, immediately behind cirrus sac. Ovary transversely elongated or somewhat oval, situated between testes mostly to left side. Receptaculum seminis pear-shaped, to right side immediately in front of posterior testis. Transverse vitelline ducts closely behind ovary and proximal end of uterus or metraterm ; vitelline reservoir to left side immediately behind left transverse vitelline duct. Cirrus sac large, elongated, nearly straight or slightly curved in semilunar manner, thin-walled, slightly muscular and situated with long axis parallel to length of body to right side between genital opening and anterior testis, containing internal seminal vesicle, pars prostatica with numerous prostate gland cells and short unarmed eversible cirrus. External seminal vesicle situated to right side outside basal part of cirrus sac. Metraterm long, muscular, narrower proximally and much broader, somewhat swollen near distal end, situated to left side opposite to cirrus sac ; uterus indistinguishable from proximal part of metraterm, containing only one long, slightly coiled tubular ovum of 0·325 mm. length and 0·02 mm. maximum breadth. Vitellaria well developed, overlapping intestinal cæca, extending from just behind ventral sucker to a short distance in front of hinder end, uniting mesially behind posterior testis to form a large post-testicular mass. Parasitic in small intestine of fresh water turtles.

Type species : Enterohæmatotrema palæorticum n. sp.

Enterohæmatotrema palæorticum n sp.

(Fig. 1)

Eight specimens of which four were mature were obtained from the small intestine of three turtles of the species *Lissemys punctata* Malcolm Smith, three from two hosts each and two from the third host. This parasite appears to be rare ; only three out of many hosts examined were found infected with it. They were more or less intimately attached to the intestinal wall and took about half an hour to come out when the intestine was opened in salt solution, in which they moved actively by lashing movements like small nematode worms. Body minute, slender, elongated and delicate, usually tapering towards both ends, posterior end pointed ; short anterior part of body in front of ventral sucker narrow and prolonged as a neck region. Length of mature specimens 1·8—2 mm., of relatively immature specimens 1 – 1·2 mm. and maximum breadth 0·234 mm. in the region of testes and ovary. Body wall entirely devoid of spines or verrucæ. Oral sucker subterminal, oval or somewhat cup-shaped and protrusible like that of blood flukes, 0·06—0·072 mm. in length and 0·042—0·051 mm. in breadth. Ventral sucker transversely elongated, 0·091—0·096 × 0·06—0·072 mm. in size, situated at about one-third to one-fourth body length from anterior end, *i.e.*, 0·44--0·57 mm. from it. Pharynx absent; œsophagus

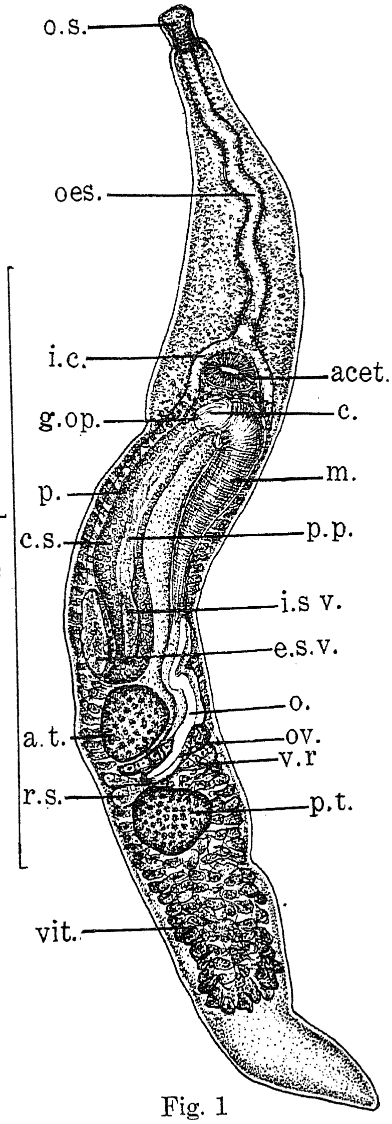


Fig. 1

Ventral view of *Enterohaematotrema palaeorticum* n. g. n. sp.

acet., acetabulum; *a.l.i.c.*, anterior loop of intestinal caecum; *a.t.*, anterior testis; *c.*, cirrus, *c.s.*, cirrus sac; *d.c.*, diverticula of common caecum; *ex.b.*, excretory bladder; *e.s.v.*, external seminal vesicle; *e.v.f.*, extracaecal vitelline follicles; *g.op.*, genital opening; *g.l i.c.*, genital loop of right intestinal caecum; *g.l.l.i.c.*, genital loop of left intestinal caecum; *g.v.*, glandular vesicle; *i.c.*, intestinal caecum; *i.s.v.*, internal seminal vesicle; *m*, metraterm; *mo.*, mouth; *o.*, ovum; *oes.*, oesophagus; *oes.v.*, oesophageal vesicle; *o.v.*, ovary; *o.s*, oral sucker; *p.*, prostate gland cells; *p.p.*, pars prostatica; *p.t.*, posterior testis; *r.s.*, receptaculum seminis; *s.g.*, salivary gland cells; *s.m.*, shell gland mass; *t.*, testis; *ut.*, uterus; *u.v.d.*, unpaired vitelline duct; *vit.*, vitellaria; *vit.f.*, vitelline follicles; *v.r.*, vitelline reservoir.

long and sinuous with two or three bends, slightly dilated at its end just in front of intestinal bifurcation and surrounded by a large number of gland cells, measuring 0·4—0·52 mm. in length and 0·021— 0·03 mm. in greatest breadth ; median œsophageal vesicle behind origin of intestinal cæca at intestinal bifurcation characteristic of *Spirorchis* and *Plasmiorchis* absent; intestinal bifurcation just in front of ventral sucker; intestinal cæca pass laterally one on each side of ventral sucker, narrow confined to lateral edges of body up to the hinder end of posterior testis and covered by vitellaria, terminating at 0·312—0·338 mm. distance, *i.e.*, one-sixth to one-eighth, body length in front of hinder end, undulating slightly behind testes but not converging mesially towards each other behind ventral sucker as in the genus *Cœuritrema*. Genital opening median on ventral side immediately behind ventral sucker, in front of middle of body length, at 0·52 – 0·62 mm. distance from anterior end in a specimen of 1·8—2 mm. length. Testes two in number with ovary between them, subspherical or somewhat ovoid, situated in posterior half of body immediately behind cirrus sac, slightly to right side in same line with one another; anterior testis 0·52—0·58 mm. behind acetabulum, measuring 0·117—0·12 mm. in diameter or 0·117—0·12 mm. in size; posterior testis slightly larger than anterior testis, situated 0·065 mm. behind the latter and 0·494—0·5 mm. in front of hinder end, measuring 0·135 mm. in diameter or 0·169 × 0·13 mm. in size. Ovary with a compact mass of ova of large size at its inner end, transversely elongated or somewhat oval, situated between testes to left side nearer anterior than posterior testis, measuring 0·06 × 0·036 mm. in size Receptaculum seminis thin-walled, pear-shaped and filled with sperms, situated to right side closely inside right intestinal cæcum, immediately in front of posterior testis and just behind transverse vitelline duct of that side, measuring 0·063 mm. in length and 0·036 mm. in maximum breadth. Laurer's canal not seen. Cirrus sac large, thin-walled slightly muscular, elongated, longer than that of *Cœuritrema*, nearly straight except the slightly curved basal part or slightly curved throughout its length in a crescent-shaped manner with concavity on its inner border, situated to right side with long axis parallel to body length between genital opening and anterior testis, measuring 0·52—0·6 mm. in length and 0·091—0·13 mm. in maximum breadth, at about middle of its length or a little above the base. External seminal vesicle thin-walled, somewhat U-shaped consisting of large oval or elliptical and narrow tubular parts slightly overlapping one another, situated to right side overlapping right intestinal cæcum near body wall a little in front of anterior testis outside basal part of cirrus sac, and filled with sperms, measuring 0·108—0·11 mm. in length and 0·036 mm. in greatest breadth. Internal seminal vesicle contained in basal part of cirrus sac, straight, narrow, filled with sperms, 0·12—0·195 mm. in length and 0·024—0·027 mm. in greatest breadth; pars prostatica long, narrow, tubular, 0·338—0·36 mm. in length and 0·027 – 0·03 mm. in maximum breadth ; cirrus protrusible, short and somewhat conical when protruded, found inserted in the type specimen in distal end of metraterm,

measuring 0·05 – 0·065 mm. in length and 0·03 mm. in greatest breadth at the base; prostate gland cells numerous around seminal vesicle and proximal half of pars prostatica, small number around distal half of the latter. Ootype passes just behind ovary into uterus, which continues insensibly into large muscular metraterm, both forming together a prominent tube of great length, narrow proximally, broad and dilated at distal end, situated to left side parallel to anterior testis and cirrus sac, overlapping ovary and measuring 0·585 mm. in length, 0·052—0·078 mm. in greatest breadth at distal end and 0·026 mm. in narrowest diameter at proximal end. Shell gland cells absent. Only one ovum contained at a time in uterus or proximal part of metraterm; ovum long, narrow, bent twice or somewhat coiled, produced into a bluntly pointed process at each end, measuring 0·325 mm. in length and 0·021 mm. in greatest breadth. Vitellaria composed of moderately sized or large follicles overlapping and outside cæca, commencing immediately behind acetabulum and terminating a little distance, *i.e.*, 0·28 mm. in front of hinder end of body, confined to lateral edges of body near body wall in front of anterior testis, but united behind posterior testis to form a large post-testicular mass of large follicles filling the body in this region. A few follicles pass inwards behind acetabulum to unite vitellaria anteriorly in front of genital opening. Transverse vitelline ducts arise from vitellaria just behind ovary and closely in front of posterior testis; vitelline reservoir a pear-shaped mass of follicles filled with yolk granules, situated to left side immediately behind ovary.

Host.—*Lyssemys punctata* Malcolm Smith.

Location.—Small intestine.

Locality.—Allahabad, India.

Remarks:—The genus *Enterohæmatotrema* bears close resemblance to the blood flukes of the genus *Cœuritrema* Mehra on account of the absence of the pharynx, great length of the œsophagus, position of the testes with the ovary between them in the posterior half of body with the well developed cirrus sac, external seminal vesicle and metraterm in front, post-acetabular position of the genital opening in front of the gonads and far in front of the hinder end and similarity in the position of the receptaculum seminis and vitellaria. But it dffers remarkably in the median pre-equatorial position of the genital opening on ventral side of the body just behind acetabulum (in *Cœuritrema* genital opening is dorsal, sinistral, close behind acetabulum near middle of body length), in the shape and position of the cirrus sac and metraterm, which are much more elongated and lie parallel to one another along the long axis of the body, and above all in the habitat in the gut instead of the heart and arteries of the turtle. The new genus belongs to the subfamily Hapalotreminæ of the family Spirorchidæ on account of the general topography and falls into the group of the two genera *Cœuritrema* Mehra and *Hapalorhynchus* Stunkard on account of the presence of two testes separated by the ovary.

As discussed by us previously (1939), we do not agree with Byrd (1939), who follows Price (1934) in considering *Coeuritrema* to be synonymous with *Hapalorhynchus*, and the description of three new species of the latter genus by Byrd (1939) confirms our opinion. In *Hapalorhynchus stunkardi* Byrd the much larger vesicula seminalis occupies a different position from that in *Coeuritrema* and the large mass of large prostate gland cells surrounds the cirrus sac quite unlike that in the latter genus, in which the prostate gland cells lie within the cirrus sac. Moreover, the cirrus and metraterm are poorly developed and slightly muscular in *H. stunkardi*, reverse to that in *Coeuritrema*. The shape of the ovum also differs. The cirrus sac and metraterm are indistinguishable or poorly developed in *H. evaginatus* Byrd, but they are well developed in *Coeuritrema*. *H. reelfooti* Byrd, however, stands closer to the latter genus on account of the prostate gland cells being enclosed within the slightly muscular cirrus sac, but the cirrus seems to be poorly developed, the metraterm is absent, and the external seminal vesicle is much larger and occupies a different position.

Subfamily Spirorchinæ Stunkard.

Hemiorchis hardellii Mehra (1939) (syn. *Plasmiorchis hardellii* Mehra 1934). (Fig. 2)

A number of these blood flukes were obtained recently from the ventricle of the heart and aortic arches of two *Hardella thurgi* at Allahabad. To the detailed account of this species given in 1934 a few more points are added.

Length 4—4·5 mm.; greatest breadth 1·05—1·12 mm. in acetabular region or a little behind it. Fine needle-like spines of 0·015 mm. length lie within cuticle of about the same thickness and do not project outside it. External seminal vesicle very small, rather inconspicuous, situated outside basal end of cirrus sac between hindmost testis and ovary. Cirrus sac large with thick muscular walls, situated obliquely to left side opposite ovary with basal end in level with or a little in front of it and terminal end surrounded by genital loop of left intestinal cæcum behind it, measuring 0·225 mm. in length and 0·108– 0·12 mm. in greatest breadth. Internal seminal vesicle long and much coiled; numerous prostate gland cells surrounding internal seminal vesicle and small rounded pars prostatica; ejaculatory duct or cirrus with muscular walls short and curved. Ovary small, lobed, situated to right side closely inside right cæcum, just in front of and sometime partly overlapping inwardly pointed bent end of genital loop of that cæcum, a little distance behind hindmost testis, broader than long, measuring 0·075—0·12 × 0·18–0·195 mm. in size. Ovum single, oval, without polar filaments, 0·075—0·08 × 0·027—0·03 mm. in size. Transverse vitelline ducts situated a little behind ovary; vitelline reservoir small, median, just in front of transverse vitelline ducts.

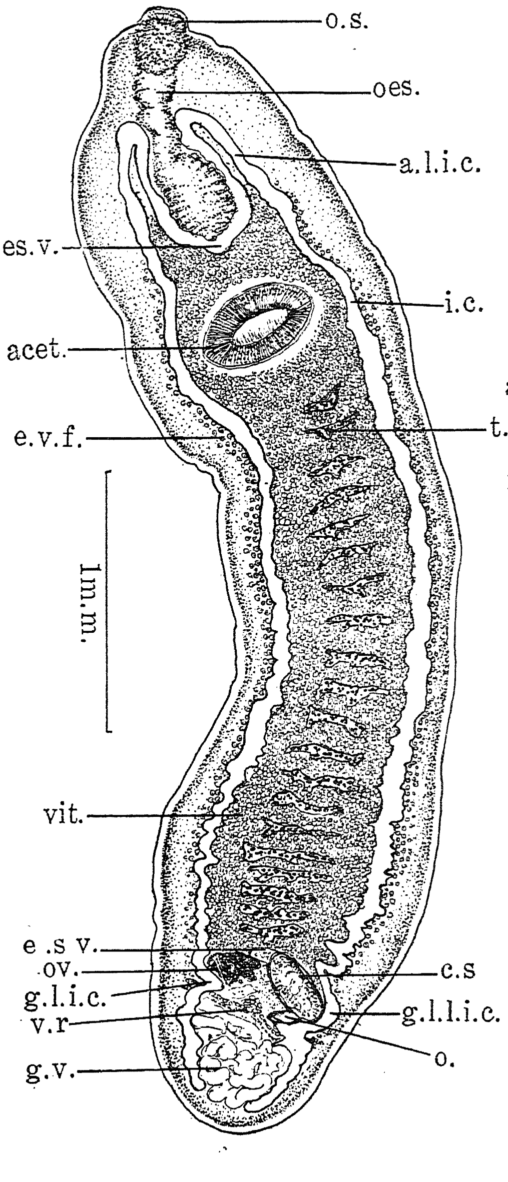


Fig. 2
Ventral view of *Hemiorchis bardellii* Mehra.

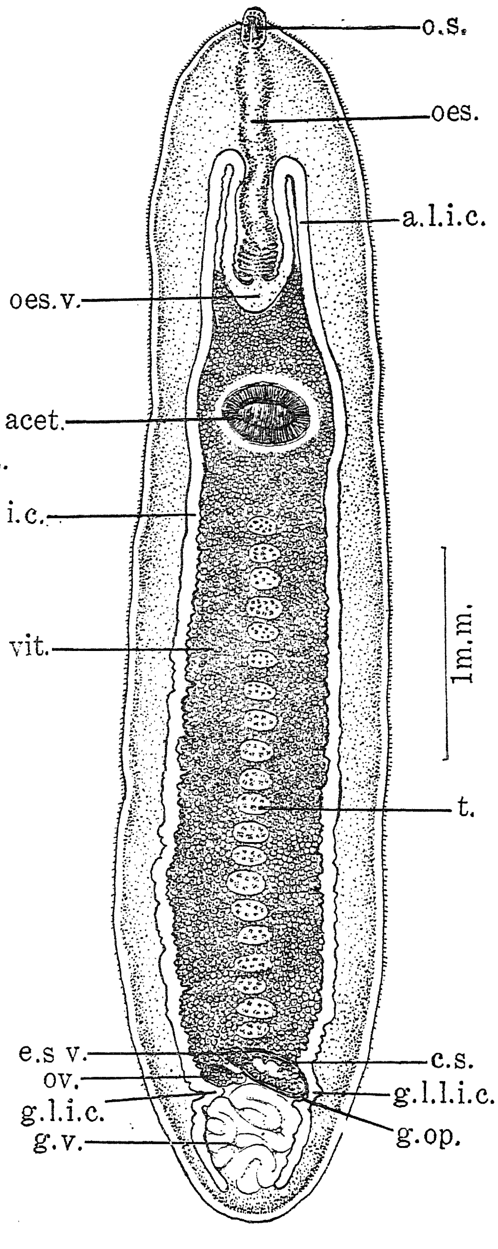


Fig. 3
Ventral view of *Hemiorchis bengalensis* n. sp.

(Lettering as in Fig. 1)

Vitellaria forming one large mass of numerous small rounded follicles occupying characteristically entire intercæcal region around acetabulum and testes from intestinal bifurcation or a little further in front to anterior margin of ovary and cirrus sac, and also composed of a small number of extracæcal follicles forming a narrow fringe immediately outside cæca. The entire intercæcal parenchymatous tissue around acetabulum and testes from the intestinal bifurcation and within basal parts of forwardly directed loops to the ovary is developed into a large mass of small deeply staining vittelline follicles, which forms a characteristic feature of the genus *Hemiorchis*. On a re-examination of the entire mounts on which our previous account of this species was based this description of the vitellaria is confirmed, and it must be admitted that the large characteristic intercæcal vitellarian mass described above was inadvertently overlooked at that time.

Hemiorchis bengalensis n.sp.

(Fig. 3)

Host.—*Hardella thurgi* Boulenger.

Location —Ventricle of heart.

Locality.—Rana Ghat, Bengal.

Four specimens of this blood fluke were collected by Mr. R. C. Chatterji from the ventricle of the heart of one fresh water tortoise, *Hardella thurgi* obtained from Rana Ghat, Bengal and dissected in the Zoological laboratory of the Allahabad University in April 1940. My best thanks are due to Mr. R. C. Chatterji for giving me two specimens for study.

Body thin, transparent, elongated, and elliptical with rounded anterior and posterior ends; anterior end broader. Length in entire mounts 6 mm.; maximum breadth 1·27 or 1·035 mm. at a little behind middle of testicular region; breadth in acetabular region 1·11 or 0·81 mm.; breadth in region of ovary 0·99 or 0·705 mm. respectively in the two specimens examined. The body is narrower and more elongated than in type species. Body wall armed with minute pointed denticles or spines projecting outside thin cuticle unlike those in the type species. Oral sucker oval, longer than broad, slightly protrusible, 0·204 or 0·188 mm. in length, 0·155 or 0·132 mm. in maximum breadth respectively. Acetabulum stouter, slightly broader than long, about one and a half time larger than oral sucker, 0·27×0·333 and 0·237×0·25 mm. in size in the two specimens respectively, and situated at 1·65—1·75 mm. from anterior end, *i.e.*, at about one-third body length from the latter. Pharynx absent; œsophagus long and slightly undulating with two bends, 1·215 and 1·125 mm. in length in the two specimens, *i.e.*, about one-fifth part of the body length, and uniform in breadth except at ends; deeply staining salivary gland cells prominently developed and much larger in number around terminal part of œsophagus; œsophageal vesicle larger and more prominent than that in *Hemiorchis hardellii*.

Intestinal cæca arise laterally from œsophageal vesicle and pass anteriorly as forwardly directed loops lying parallel to œsophagus for two-third to three-fourth of its length; behind acetabulum cæca provided with indented margins or minute irregular diverticula specially on inner side; genital loops well developed as in type species, that of left cæcum semicircular and wider with genital opening inside it and that of right cæcum with bent end directed inward just behind ovary. Glandular vesicle in the form of a large convoluted tubular mass filling entire intercæcal space behind ovary and cirrus sac, in the region marked anteriorly by genital loops and pressed laterally against walls of cæca. Excretory opening dorsal a little in front of hinder end; excretory bladder V-shaped, bend of the V broad and situated just behind glandular vesicle and blind ends of cæca, narrow tubular cornua not seen beyond the latter on account of their being overlapped by cæca.

Testes 20 in number and arranged in a regular linear series in median line, separated from one another by a little distance and from cæcum on either side by a considerable distance, commencing 0·52 or 0·36 mm. behind acetabulum, oval in shape with entire margins and broader than long, 0·126—0·135×0·09 mm. in size in fully mature specimen, and smaller and somewhat rounded, 0·05—0·06× 0·045 mm. in less mature specimen. The new species differs from *H hardellii* in the shape and size of testes. Vesicula seminalis externa moderately sized, somewhat oval, 0·07—0·12×0·015—0·075 mm. in size, filled with sperms, and situated slightly to right side between hindmost testis and ovary partly overlapping basal end of cirrus sac. Cirrus sac large with thick muscular walls, situated semiobliquely to left side just behind hindmost testis and immediately in front of glandular vesicle with basal end in median line just in front of ovary and terminal end a little behind the latter, measuring 0·288—0·3 mm. in length and 0·081—0·12 mm. in maximum breadth. Internal seminal vesicle long and slightly coiled surrounded by numerous prostate gland cells; pars prostatica small; muscular ductus ejaculatorius or cirrus short and curved. Genital opening on left side just inside left cæcum within its genital loop, at 0·55—0·6 mm. in front of hinder end.

Ovary subspherical with a small oval mass of large ova protruding from its inner side, transversely elongated, 0·159×0·09 mm. in size inclusive of the inner mass of large ova of 0·066×0·045 mm. size, situated to right side closely inside and touching inner margin of right cæcum just in front of bend of right genital loop, 0·09 mm behind hindmost testis and at about one-ninth part of body length from hinder end; oviduct arising from hinder end of inner margin of ovary runs backwards; receptaculum seminis rounded, situated a little behind ovary to right side, 0·06 mm. in diameter; shell gland cells and Laurer's canal not seen; metraterm present; ovum single, large, oval, without polar filaments, 0·09 mm. in length and 0·06 mm. in greatest breadth. Vitellaria exclusively intercæcal, forming one huge

mass of numerous small rounded follicles around acetabulum and testes from intestinal bifurcation or origin of œsophageal vesicle to ovary, external seminal vesicle and cirrus sac. The entire intercæcal parenchymatous tissue in front of the latter organs is developed around and in front of the testes into the large mass of vitelline follicles. In this species the vitelline follicles are entirely absent outside the cæca. Transverse vitelline ducts lie just in front of glandular vesicle behind ovary, with small vitelline reservoir in front more or less in median line.

Remarks.—*Hemiorchis bengalensis* n. sp. is distinguished from *Hemiorchis* (syn. *Plasmiorchis*) *hardellii* Mehra by the narrow and more elongated shape of the body, cutaneous spines projecting outside the cuticle, larger size of the œsophageal vesicle, shape of the testes (oval with entire margins in *bengalensis*, narrow, transversely elongated and irregularly lobed in *hardellii*), moderate size of the external seminal vesicle, shape of the ovary, exclusively intercæcal position of the vitellaria and difference in size of the various organs.

Hemiorchis Mehra, 1939.

Generic diagnosis.—Spirorchidae. Spirorchinae. Hermaphrodite distome blood flukes. Body small, thin, elongated, flattened, somewhat elliptical with rounded anterior and posterior ends; cuticular spines present. Oral sucker oval, longer than broad, slightly protrusible; acetabulum stouter and larger than oral sucker, broader than long, situated at about one-third body length from anterior end. Pharynx absent; oesophagus long, sinuous, surrounded by numerous salivary gland cells near its distal end; oesophageal vesicle present; intestinal caeca with forwardly directed loops one on each side of oesophagus, terminating near hinder end of body, and forming well marked genital loops, right loop short and bent inwards just behind ovary and left loop semicircular just outside genital opening. Glandular vesicle in the form of a large convoluted tubular mass filling entire intercæcal space near hinder end behind ovary and genital opening. Excretory opening dorsal, a little in front of hinder end; excretory bladder V-shaped, bend of the V broad and situated just behind glandular vesicle and blind ends of cæca. Genital opening ventral to left side, closely inside left cæcum in its genital loop, just behind ovary and a short distance in front of hinder end. Testes large in number, arranged in a regular linear series in median plane between cæca a short distance behind acetabulum and in front of ovary. External seminal vesicle small or moderate sized. Cirrus sac large with thick muscular walls, situated obliquely or semi-obliquely to left side behind hindmost testis opposite ovary, enclosing long, coiled internal seminal vesicle and small pars prostatica surrounded by numerous prostate gland cells and short ductus ejaculatorius or cirrus. Ovary small, to right side closely inside right cæcum just in front of small right genital loop, a little distance in front

of hinder end; receptaculum seminis and metraterm present. Vitellaria mostly forming one characteristic large intercæcal mass of numerous small rounded follicles around and in front of acetabulum and testes from intestinal bifurcation or a little in front to ovary and a narrow fringe of extracæcal follicles just outside cæca, or exclusively intercæcal forming the large characteristic mass mentioned without fringe of extracæcal follicles; transverse vitalline ducts just behind ovary with small median vitelline reservoir just in front. Ovum single, large, oval, without polar filaments. Parasitic in ventricle of heart and arteries of fresh water turtles, India.

Type species: *Hemiorchis hardellii* Mehra, 1939 (syn. *Plasmiorchis hardellii* Mehra, 1934).

Family Schistosomatidæ Poche.

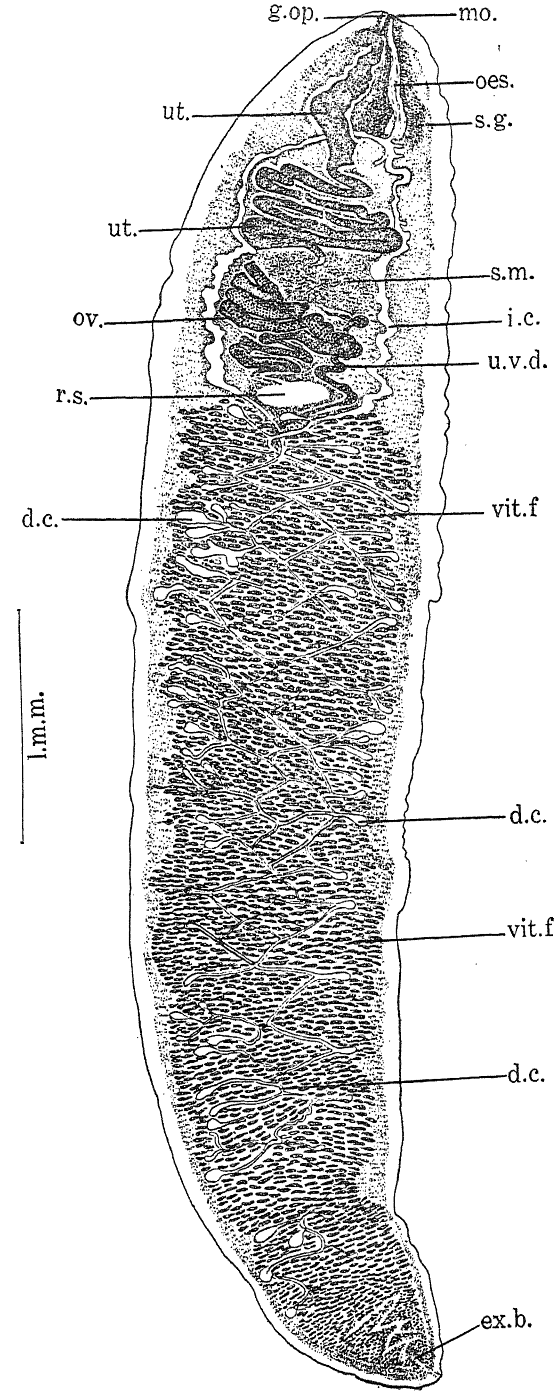
Subfamily Dendritobilharzinæ n. subf.

Dendritobilharzia asiaticus n. sp.

(Figs. 4 & 5)

One female blood fluke of this species was obtained from a branch of the anterior mesenteric vein of the common teal, *Nettion crecca crecca* caught at Allahabad. The male is unknown. Body small, elongated, flattened, somewhat tongue-shaped, narrower at ends with more or less rounded anterior and bluntly pointed posterior ends. Length 6 mm., maximum breadth 1·3 mm. immediately behind posterior union of cæca, breadth in region of ovary 1·26 mm.; cuticle thin, devoid of spines or tubercles. Suckers absent. Mouth subterminal, ventral, near anterior end, rounded, very small, 0·012 mm. in diameter, armed internally with very minute cuticular denticles; pharynx absent; œsophagus 0·5 mm. long, surrounded by salivary gland cells forming a relatively thin layer around anterior third and a thick bulb-shaped mass around posterior third of its length; œsophageal bifurcation at 0·52 mm. from anterior end. Intestinal cæca narrow near their origin and their posterior union, sinuous, provided with a few short lobe-like or tubular outgrowths; posterior union of cæca at 1·2 mm. from œsophageal bifurcation and at about one-fourth body length from anterior end; common cæcum long, zigzag, branched, reticular and provided with short lateral club-shaped, tubular diverticula, which intermingled with and surrounded by numerous vitelline follicles from a large complicated mass filling almost the entire body behind posterior union of cæca.

Genital opening terminal at anterior end, close and to right side of oral opening. Ovary intercæcal, situated mostly to right side near right cæcum a little in front of posterior union of cæca, at 1·05 mm. distance behind anterior end, very long and much coiled, consisting of seven large loosely arranged spiral coils placed closely behind one another, measuring 2·8 mm. in length and 0·063 mm. in greatest breadth; anterior or proximal four coils composed of primordial ova pressed against one



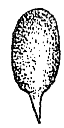


Fig. 5

Fig. 4.—Ventral view of female *Dendritobilharzia asiaticus* n. sp.
Fig. 5.—Ovum of *Dendritobilharzia asiaticus* n. sp.
(Lettering as in Fig. 1)

another, posterior or distal three ovarian coils short, narrow, and composed of 4—6 rows of large mature ova. Oviduct a continuation of narrow posterior end of ovary; receptaculum seminis oval, 0·24 × 0·09 mm. in size, situated median behind ovary just in front of posterior union of cæca, with oviduct at its anterior margin slightly to right side. Vitellaria unpaired, composed of numerous pear-shaped follicles mixed up with and surrounding dendritic diverticula of the common cæcum, occupying almost entire body from cæcal union to posterior end; unpaired vitelline duct prominent, sinuous, in intercæcal space contiguous and to right side of posterior four coils of ovary, arising from vitelline mass at posterior union of cæca. Uterus large, convoluted, arising from anterior margin of shell gland mass near median line at about 0·52 mm. behind œsophageal bifurcation, composed of four large convolutions filling entire intercæcal space a little behind œsophageal bifurcation and passing forwards as a large compact mass of ova in front of the latter to right side of œsophagus to open at the genital opening. Ova numerous, with fairly thick yellow brown shell, nearly oval and produced at one end into a short pointed spine measuring 0·027—0·033 mm. in length including the spine, and 0·015—0·018 mm. in maximum breadth.

Host.—*Nettion crecca crecca* Stuart Baker.

Location.—Branch of anterior mesenteric vein.

Locality.—Allahabad.

Remarks:—The genus *Dendritobilharzia* was created in 1920 by Skrjabin and Zakharow for *Dendritobilharzia odhneri*, which was later (1924) recognised by Skrjabin to be identical with *Bilharziella pulverulenta* Braun, 1901. Both the accounts of the type species *Dendritobilharzia pulverulenta* (Braun, 1901) Skrjabin, 1924 by Braun and Skrjabin and Zakharow were based on the description of the male specimen obtained from *Querquedula querquedula* (*Anas querquedula*) in Africa (Dongola, Sudan) and Europe (Russia). The female of this species, which is much smaller than the male, *i.e.*, 1·5657 mm. long by 0·2875 mm. wide, was described by Semenov from *Anas platyrhynchos* (*A. boschas*) in 1927 from Russia. The second species of this genus, *Dendritobilharzia loossi* Skrjabin was described by Skrjabin in 1924 from the female specimen obtained from *Pelecanus onocrotalus* in Russia (Europe). The female of this species which is much larger in size than that of the type species is also inadequately described. Though Skrjabin's paper (1924), giving its description is inaccessible to me, the meagre account reproduced by Price (1929) mentions the absence of oral sucker and acetabulum, 0·45 mm. as the length of the œsophagus, position of the posterior union of the cæca about 3·47 mm. from the œsophageal bifurcation, common cæcum as in *D. pulverulenta*, the spiral tubular ovary and unpaired vitelline duct in the space between intestinal cæca and vitelline follicles situated along the course of the common cæcum. The new species which is described from a female specimen and represents the third species of the genus,

is easily separated from the type species by the much larger size of the female, the body not divided into two parts by an irregular transverse groove, and the large size and coiled form of the ovary (ovary 2·8 mm. long by 0·063 mm. broad in the new species, 0·1028 mm. long by 0·0914 mm. in *D. pulverulenta*). It differs from *D. loossi* in size (female 14·2 mm. long by 1·41 mm. wide in *loossi* and 6 mm. long by 1·3 mm. broad in *asiaticus* n. sp.), in the posterior union of the cæca at 1·2 mm. from the œsophageal bifurcation (in *loossi* 3·47 mm. from œsophageal bifurcation), in the coiled form of the ovary and the uterus filled with numerous ova. It may also be remarked that the large convoluted uterus filled with numerous ova and terminal position of the genital opening at the anterior end in the female, which are so characteristic of the new species have not been observed in *D. loossi*.

We exclude the genus *Dendritobilharzia* from the subfamily Bilharziellinæ and create a new subfamily Dendritobilharzinæ for it on account of the long common cæcum provided with lateral dendritic branches, large convoluted uterus filled with numerous ova, anterior terminal position of the genital opening in the female and numerous vitelline follicles along with lateral branches of the common cæcum almost filling the whole body behind the cæcal union. It appears that from the form like *Bilharziella* have been evolved along one line of evolution the genera of the subfamily Schistosomatinæ and along the other two separate lines the genera *Dendritobilharzia* and *Gigantobilharzia*. The genus *Chinhuta* Lal, 1937 resembles *Bilharziella* closely except in the presence of a gynæcophoric canal, which in our opinion is absent in it. According to Lal the lateral edges of body in *Chinhuta* are rolled inwards to form a deep gynæcophoric groove, which extends right from the hinder end of the oral sucker to the posterior end. The gynæcophoric canal in the subfamily Schistosomatinæ, as is well-known, extends from behind the acetabulum and not from behind the oral sucker and, moreover, Lal does not mention whether he found any female specimen enclosed in the gynæcophoric canal of the male, specially when he collected about 200 specimens from the same host. Arnaldo Giovannola (1936) even in unisexual infection with *Schistosoma mansoni* found three couples, all males, in the copula position, and the three males observed in the gynæcophoric canals of other males were of smaller size. So Lal's observation on the presence of a gynæcophoric canal in *Chinhuta* is not at all convincing, on the other hand what he calls by this name appears to be a depression on the ventral side, which ordinarily occurs in some distomes due to contraction during fixation or the dying state of the worm. The position of the ovary in the figure by Lal outside the common cæcum just behind the posterior cæcal union requires to be confirmed, as its usual position in the family is intercæcal in front of the posterior union of the cæca. The morphology of both the male and female specimens of *Chinhuta* resembles so closely that of *Bilharziella*, that we are constrained to drop this genus and assign its species to the latter genus as *Bilharziella indica* (Lal, 1937) Mehra, 1940.

Dendritobilharzinæ n. subf.

Subfamily diagnosis.—Schistosomatidæ. Body of both sexes elongated, flattened and similar in form. Gynæcophoric canal absent. Suckers absent. Paired intestinal cæca short; common cæcum long and provided with lateral dendritic branches. Genital opening in male in anterior part to left side just in front of posterior cæcal union, in female terminal at anterior end. Testes numerous, about 110 in number, situated in a zigzag line along the common cæcum from cæcal union to posterior end. Ovary spiral or coiled, intercæcal; uterus large, coiled and filled with numerous ova. Vitelline follicles numerous, mixed up with dendritic branches of common cæcum, filling almost entire body behind posterior cæcal union.

Type genus.—*Dendritobilharzia* Skrjabin and Zakharow, 1920.

Gigantobilharzinæ n. subf.

Subfamily diagnosis.—Schistosomatidæ. Body of both sexes very long, elongated, cylindrical, female shorter than somewhat flattened male; posterior extremity of both sexes provided with lateral lobe-like projections Oral sucker usually absent, seldom present. Ventral sucker always absent. Gynæcophoric canal absent or rudimentary. Paired intestinal cæca short; common cæcum very long without lateral branches. Genital opening in male between œsophageal bifurcation and cæcal union, in female median much in front of œsophageal bifurcation, near anterior end. Testes very numerous, more than four hundred in number, from behind cæcal union to hinder end. Ovary moderately long, spiral. Vitelline follicles occupying about nine-tenths of body length. Uterus short containing a few ova.

Type genus.—*Gigantobilharzia* Odhner, 1910.

The subfamily Bilharziellinae Price, 1929 is retained for the genera *Bilharziella* Looss, 1899 and *Trichobilharzia* Skrjabin and Zakharow, 1920.

Remarks on the Evolution of the Blood Flukes

Odhner (1912) while discussing the affinities of *Hapalotrema* with *Liolope*, *Bilharziella*, *Ornithobilharzia*, and *Bilharzia* traced their origin from the intestinal distome, *Liolope* Cohn. He derived the *Bilharzia* type from the blood fluke *Hapalotrema*, which he included with the intestinal distomes *Liolope* and *Helicometra* in the subfamily Liolopinae, family Harmostomidae, and deferred to a subsequent paper a discussion of the affinities of the blood flukes of fishes, the Aporocotyle-Sanguinicola series. Stunkard (1921 and 23) on the basis of a close similarity of *Spirorchis* with *Aporocotyle* recognised that the Aporocotylidae of fishes, the Spirorchidae of turtles and the Schistostomidae of birds and mammals from a well defined group with inherent natural relationships. He put forward the view that the Spirorchidae stand in an intermediate position, and that the Schistosomes are to

be derived through them from the Aporocotylidae rather than from the Harmostomidae as maintained by Odhner. According to him the blood flukes originating with the most degenerate suckerless forms with reduced alimentary tract, *Sanguinicola* and *Aporocotyle* were evolved through *Spirorchis* and *Hapalotrema* to *Schistosomes*. Poche (1925) did not accept Stunkard's view saying that the absence of suckers and the presence of follicular testes in the Aporocotylidae and Sanguinicolidae warrant against it.

La Rue (1926) established that the Strigeidæ, Schistosomatoidea and Gasterostomata are genetically related, and accordingly proposed a single order Strigeatoidea to include them under the three suborders Strigeata, Schistosomata and Bucephalata. Szidat (1928) mainly on the basis of the life history studies pointed out the affinities of the Harmostomidæ (*Harmostomum leptostomum*, *Urogonimus macrostomum*), *Clinostomum* and *Sphærostomum* with the La Rue's order Strigeatoidea, mentioning that they have secondarily lost the tailed cercarial larval stage in their development. He finds himself in agreement with Odhner on the phylogeny of these forms based on the comparative anatomy studies. According to him the ancestral form of the Strigeatoidea, Sanguinicolida, Harmostomidea, Clinostomidea stands nearest to *Sphærostoma bramæ*, from which he derives La Rue's suborders along two lines of evolution, one passing through *Liolope copulans* to the blood flukes of reptiles, birds and mammals and the other passing into the suborder Strigeata, the immediate hypothetical ancestor of which is not known to be connected with any living representative. He thinks that the Bucephalata originated at the root of the Strigeata branch and are closely related to its primitive genera *Cyathocotyle* and *Prohemistomum*, with which they show much resemblance in the position of the genital organs and the presence of a cirrus sac.

We in 1933 supported Odhner's view about the orgin of the Schistosomatidæ from *Hapalotrema* through *Liolope* and postulated that the subfamily Hapalotreminæ of the Spirorchidæ formed the central stock from which have been evolved along one line the Spirorchinæ, and through *Spirorchis* the Aporocotylidæ and the more degenerate Sanguinicolidæ, and along the other line the Schistosomatidæ. *Coeuritrema* was considered to represent the blood fluke closely related to the ancestor through which the Hapalotreminæ have been evolved from the Liolopinæ. We rejected Stunkard's and Ejsmont's view about the phylogeny of blood flukes in an ascending series from the Aporocotylidæ, through the Spirorchinæ to the Hapalotreminæ and Schistosomatidæ on the analogy of various groups of animals that evolution always takes place in divergent lines from a central generalised type. Byrd (1939) without giving any arguments supports Stunkard that the Spirorchidæ are descendants of the more primitive Aporocotylidæ through the genus *Aporocotyle* to the genus *Spirorchis*. He gives a schematic diagram showing the probable phylogenetic

relationship among the various genera of the Spirorchidæ and with other blood flukes, which is retrograde and cannot be accepted.

There is no doubt that the blood flukes have been evolved from the intestinal distomes in the early phylogenetic history of the Digenea. The discovery of *Enterohæmatotrema* n.g. which is parasitic in the gut of turtles and is closely related to the blood flukes of the genus *Cœuritrema* adds suport to this view. The blood flukes have been parasitic in vertebrates for a long time. We are of opinion that they originated in the reptilian hosts as the Hapalotremine ancestors of the Spirorchidæ being closely related to *Enterohæmatotrema* n.g., *Cœuritrema* and *Hapalorhynchus*, a view already discussed by us in 1933. Stunkard, Ejsmont and Byrd, however, trace their origin from the suckerless degenerate forms belonging to the Aporocotylidæ parasitic in piscine hosts, mainly because the fishes are the oldest and most primitive vertebrates, and the most highly specialised blood flukes, the dioecious forms are parasitic in the most recent and highly specialised vertebrates, the birds and mammals. It has been already discussed that the morphological features involved in tracing the phylogeny of blood flukes are the number of testes, two or many, their relation to the ovary, the position of the genital opening behind the testes near the hinder end or in front of them a little behind the acetabulum, in front of or at about the middle of body length, and the presence of a well developed cirrus sac and metraterm. There is no doubt that the ancestor of blood flukes, which is represented in the intestinal distome *Enterohæmatotrema* possessed two testes, which is the most usual number for the Digenea. The division of two testes into a large number is a secondary condition met within certain genera of a few other families besides the families of blood flukes. We maintain that in the totality of organisation the generalised Fasciolid ancestor of blood flukes resembled closely *Enterohæmatotrema* and not *Aporocotyle* or *Spirorchis* as Stunkard holds. The primitive position of the genital opening in the order Fasciolata should be considered to be near the acetabulum, *i.e.*, a little in front of or behind it, but not much behind it near the hinder end. In the position of the ovary between the two testes, the ancestor of blood flukes symbolised in *Enterohæmatotrema* resembled the families of the Fasciolata, Harmostomidæ syn. Brachylæmidæ and Clinostomidæ. We, therefore, agree with Szidat that the blood flukes are evolved from the common Fasciolid ancestor of the order Stigeatoidea La Rue along one line of evolution, originating in the Liolopinæ (Harmostomidæ) which were parasitic in the reptiles developing out of amphibians. *Enterohæmatotrema*-*Cœuritrema*-*Amphiorchis* series represents the central group of the Spirorchidæ which were evolved along one line, as discussed by us before, into the Schistosomatidæ, along another line through *Hapalotrema* and *Learedius* into *Aporocotyle* *i.e.*, the Aporocotylidæ and Sanguinicolidæ while the third branch originating in *Learedius* became evolved into the remaining genera of the Spirorchinæ, *i.e.*,

Monticellius, *Hemiorchis*, *Plasmiorchis* and *Spirorchis*. The view advocated by Stunkard and Ejsmont and accepted by Byrd without comment that the blood flukes have been evolved in an ascending series from the Aporocotylidæ through the Spirorchinæ to the Hapalotreminæ and the Schistosomatidæ in co-relation with the evolution of their hosts from the most primitive vertebrates, the fishes to the most highly specialised vertebrates, the birds and mammals through the reptiles is against the fundamental concept of comparative morphology of the blood flukes and other digenetic trematodes and the evolutionary hypothesis. Evolution does not take short cuts along one line as this view contemplates. It is our conviction that the blood flukes originated in the amphibian and reptilian hosts as members of the Spirorchidæ and from the reptiles they passed on into the avian and mammalian hosts along one line as members of the Schistosomatidæ and into the piscine hosts along the other line of evolution as members of the Aporocotylidæ and Sanguinicolidæ.

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FURTHER STUDIES ON THE EFFECT OF ALCOHOL ON THE RESPIRATORY RATE OF LEAVES

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Communicated by Dr. S. Ranjan

(Received on April 28, 1938)

Summary

In this paper the effect of alcohol on the respiratory rates of the leaves of *Mangifera indica* and *Allium tuberosum* has been described. The experimental results indicate that the respiratory rate increases with the increase in the concentration of alcohol introduced into the leaves; beyond a certain concentration, however, alcohol brings about a fall in the carbondioxide output. It has been found that the acceleration of carbondioxide production by alcohol decreases with time. Lower percentages of alcohol maintain an increased respiratory rate for a longer interval of time than comparatively stronger solutions. The results are in general agreement with those obtained with the leaves of *Eugenia jambolana* described in another paper.

Introduction

The effect of alcohol on the respiratory rate of *Eugenia jambolana* leaves has been described in a previous paper[1]. In order to find out whether foliage organs of other plants respond in a similar manner to alcohol injections, experiments were performed with the leaves of *Mangifera indica* and *Allium tuberosum*. The results obtained have been analysed in a similar way as in the case of *Eugenia jambolana*.

Materials and Methods

Mature green leaves of *Mangifera indica* were chosen for this work; care was taken to ensure that the leaves selected for different experiments were of about the same age. For selecting *Allium tuberosum* leaves, the foliage organs were cut at about two inches from the ground. The older leaves could easily be distinguished by their yellow and shrivelled tips and could therefore be easily discarded. The younger healthy leaves were chosen as materials for this work.

The respiratory current was drawn through Pettenkoffer tubes containing standardised barium hydroxide solution which was ultimately titrated. Injection was carried out by means of a vacuum pump and the alcohol used was ethyl

TABLE I

Mangifera indica

	Mgms. of CO_2 per 10 gms. of leaves															
	Before injection							After injection								
Hours	3-6	6-9	9-12	12-15	15-18	18-21	21-24	24-27	27-30	30-33	33-36	36-39	39-42	42-45	45-48	48-51
Treatment ...																
Air	29·3	31·2	30·0	27·5	22·8	21·2	20·3	20·4	20·4	20·0	19·2	18·8	18·4	17·6	17·0	17·4
Water ...	28·0	32·4	30·8	25·6	23·0	21·2	20·8		23·0	20·2	19·0	18·9	18·4	18·0	17·0	17·3
2% alcohol ...	29·0	31·8	30·0	25·0	22·6	21·2	20·8		23·5	22·5	20·6	19·6	19·0	17·6	17·9	17·9
5% „ ...	29·0	32·5	30·8	28·0	24·0	22·8	21·8	Injected here	26·2	25·2	22·6	21·0	21·4	19·2	18·8	18·6
8% „ ...	31·0	33·2	31·6	28·0	23·2	21·4	21·4		27·2	28·2	25·2	21·0	21·8	19·4	19·4	18·4
10% „ ...	32·0	32·6	29·3	27·8	22·4	20·3	20·7		18·0	31·2	24·5	20·7	18·0	16·7	16·2	16·0
15% „ ...	26·3	31·0	30·2	27·3	22·6	22·0	21·4		17·2	15·1	12·6	14·0	14·5	15·0	11·3	8·6

alcohol (CH_3CH_2OH, Merck). The control sets of leaves were injected with distilled water. The various alcohol solutions also were made with distilled water. The leaves of *Mangifera indica* were allowed to respire normally for 24 hours and those of *Allium tuberosum* for 9 hours before being subjected to alcohol and water injections. For fuller details regarding experimental procedure, reference should be made to the paper on *Eugenia jambolana*[1].

Experimental Results and Discussion

The results of different experiments are given in Table I and II; in the case of water-injected leaves, instead of separate carbondioxide values in each experiment, an average respiratory rate has been given in the tables for comparison.

Table II

Allium tuberosum

Mgms. of CO_2 per 10 gms. of leaves									
Before injection			After injection						
Hours	3–6	6–9	9–12	12–15	15–18	18–21	21–24	24–27	27–30
Treatment									
Air ...	30·9	26·1	24·0	22·0	21·4	20·2	20·4	20·2	20·2
Water ...	30·8	25·6	Injected here	25·8	21·0	20·8	20·0	20·8	19·7
3% ...	30·1	26·6		29·6	25·2	23·6	22·7	22·4	21·5
5% ...	30·4	25·1		32·2	26·6	23·0	21·1	20·0	20·0

It will be seen from Tables I and II that in both the kinds of leaves, sooner or later, normal air respiration comes to a steady level phase and that injection with distilled water causes a short-lived enhancement of the respiratory rate in the case of *Mangifera indica*. If however the carbondioxide output of *Allium tuberosum* leaves after injection with distilled water be compared to that before injection, it will be found that the acceleration is almost nil. It is quite possible that the stimulus had spent itself at the time carbondioxide estimation, after water-injection, was begun, as the preliminary output of carbondioxide after each injection was neglected; and thus the respiratory rate was, possibly, measured on its downward trend after the short-lived stimulation.

The weight of alcohol entering the leaves has been shown in Table III.

TABLE III

Alcohol injected	Mgms. of alcohol entering the leaves (per 10 gms.)
M. indica	
2%	45·8
5%	130·3
8%	202·2
10%	244·9
15%	331·8
A. tuberosum	
3%	97·2
5%	169·8

It has already been seen that water-injection accelerates the respiratory rate. Therefore, as aquous solutions of alcohol were used for injection, the acceleration due to water alone should be subtracted from the acceleration produced by a solution of alcohol in water in order to derive the acceleration due to alcohol only. And, as in each experiment, water-injected leaves were used as controls, the acceleration due to alcohol alone can be found out in this way for every dilution of alcohol worked with. The data obtained in this way (from the first carbondioxide estimations after the injections) have been graphically represented, as also the amounts of alcohol entering the leaves, in Fig. 1 (*Mangifera indica*). In the case of 10% alcohol, the second carbondioxide values after injections have been taken into consideration.

As with *Eugenia* leaves,[1] the acceleration of the respiratory rate increases with increasing concentration of alcohol. A concentration beyond a 10% solution, however, brings about a fall. In the case of *Allium* leaves also increasing concentration and amount of alcohol bring about a corresponding rise in carbondioxide output (Table IV). In this case the data for higher percentages of alcohol are, however, not available and therefore the acceleration produced by higher concentrations cannot be deduced.

TABLE IV

Alcohol injected	Amount of alcohol taken in per 10 gms. of leaves	Increase in CO_2 output per 10 gms. of leaves
3%	97·2 mgms.	3·1 mgms.
5%	169·8 ,,	6·4 ,,

In order to facilitate comparison, the curves representing the effects of different alcoholic solutions have been shown in the same figures (Figs. 2 and 3 for *Mangifera*

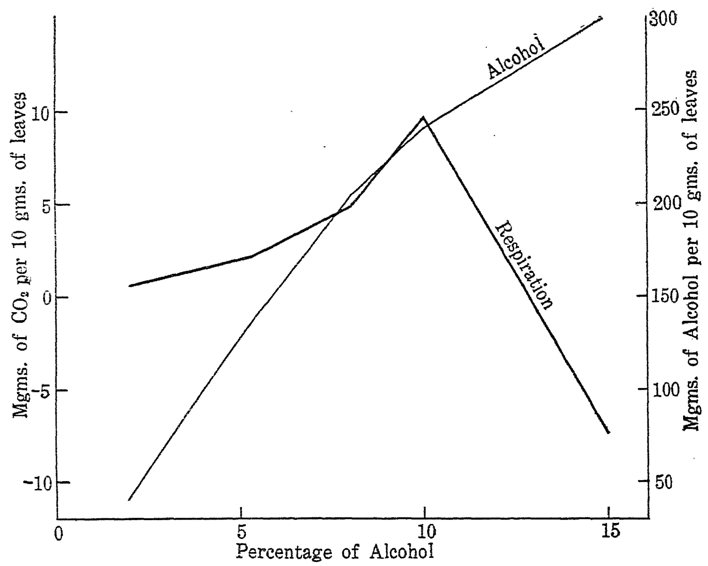

Fig. 1

The amount of alcohol entering the leaves and the respiratory rate (*Mangifera indica*)

indica and *Allium tuberosum* respectively). It will be seen that the acceleration increases with the increasing concentration of alcohol and also that the stimulation becomes feebler with the passage of time

The different curves have been produced backwards in order to obtain carbondioxide values at the zero hour of the application of the stimulus, *i.e.*, at

zero hour after the injections were made. The experimental and derived values obtained in this way of water-injected leaves have been compared in Table V.

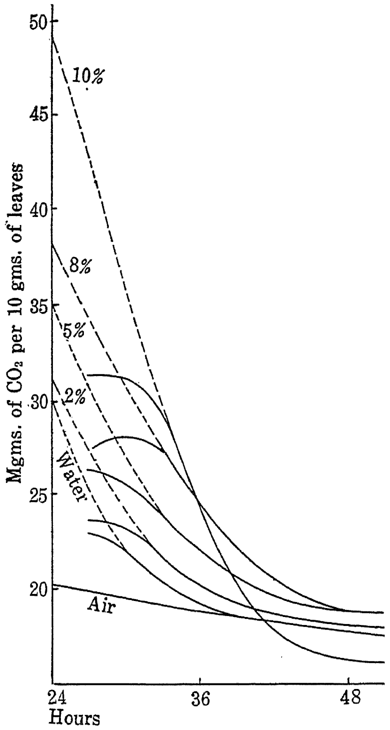

Fig. 2
The effect of different percentages of alcohol on *Mangifera* leaves

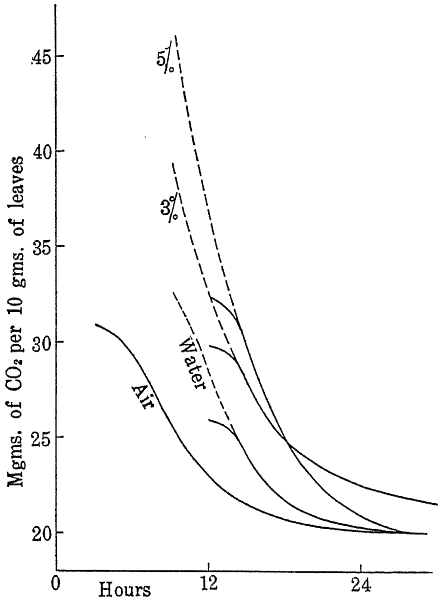

Fig. 3
The effect of different percentages of alcohol on *Allium* leaves

TABLE V

CO_2 of normally respiring leaves	CO_2 of leaves injected with water (Experimental)	CO_2 of leaves injected with water (Derived)	Acceleration by water	
			Experimental value	Derived value
M. indica 20·4 mgms.	23·0 mgms.	29·8 mgms.	2·6 mgms.	9·4 mgms.
A. tuberosum 22·0 mgms.	25·8 mgms.	32·5 mgms.	3·8 mgms.	10·5 mgms.

The first carbondioxide values after alcohol-injection and those derived by producing the curves backwards are compared in Table VI. It will be seen that the derived values stand higher; this probably indicates a higher acceleration of the respiratory rate at the zero hour or soon after the application of the stimulus, the acceleration becoming feebler with the progress of time.

TABLE VI

Alcohol injected	CO_2 of leaves injected with water (Experimental)	CO_2 of leaves injected with alcohol (Experimental)	CO_2 of leaves injected with water (Derived)	CO_2 of leaves injected with alcohol (Derived)	Acceleration by alcohol	
					Experimental value	Derived value
M. indica						
2 % ...	23·0 mgms.	23·5 mgms.	29·8 mgms	31·0 mgms.	·5 mgms.	1·2 mgms.
5 % ...	" "	26·2 "	" "	34·8 "	3·2 "	5·0 "
8 % ...	" "	27·2 "	" "	38·1 "	4·2 "	8·3 "
10 % ...	" "	31·2 "	" "	49·4 "	8·2 "	19·6 "
A. tuberosum						
3 % ...	25·8 "	29·6 "	32·5 "	39·2 "	3·8 "	6·7 "
5 % ...	" "	32·2 "	" "	46·0 "	6·4 "	13·5 "

The percentage increase of carbondioxide output due to alcohol-injection over the normal respiratory rates is shown in Table VII.

TABLE VII

Alcohol injected	Percentage increase obtained experimentally	Precentage increase from derived values
M. indica		
2%	2·5	5·9
5%	15·7	24·5
8%	20·6	40·7
10%	42·0	96·1
A. tuberosum		
3%	17·3	30·5
5%	29·1	61·4

It has been pointed out before that the acceleration of carbondioxide production by alcohol decreases with time. This has been shown graphically in Fig. 4 for *Mangifera* leaves from which it can be deduced that 5% alcohol maintains an enhanced respiratory rate for a much longer interval of time than 10% alcohol. In the case of *Allium* leaves also, the data given in Table VIII show clearly that carbondioxide production falls with time after stimulation by alcohol.

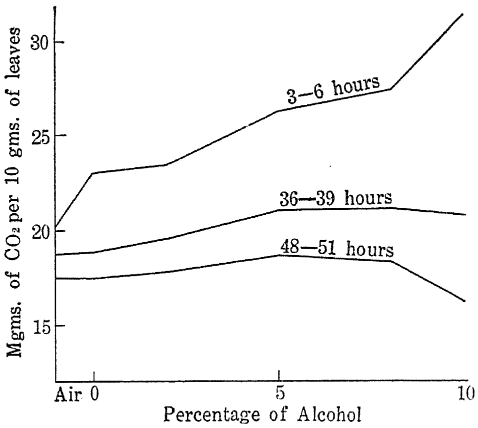

Fig. 4

Effect of alcohol as related to time (*Mangifera indica*)

TABLE VIII

Alcohol injected	Acceleration over normal respiration	
	3—6 hours after injection	12—15 hours after injection
3 %	7·6 mgms.	2·3 mgms.
5 %	10·2 ,,	·7 mgms

The time during which carbondioxide was estimated after injection was 24 hours in the case of *Mangifera indica* leaves. The total amount of carbondioxide evolved during this period by different alcohol-injected leaves have been graphically represented in Fig. 5. From this it will be apparent that 8% alcohol produces the greatest acceleration when a longer interval of time (24 hours) is considered.

As explained in the previous paper[1], the carbondioxide values for normal respiration have been derived from those of water-injected leaves by neglecting the short-lived stimulation produced by water-injection. Thus carbondioxide values for uninjected leaves for the equivalent period, during which the respiratory rates

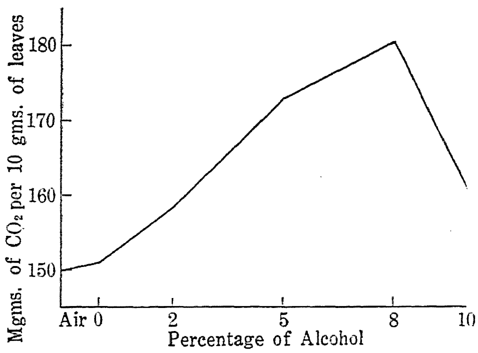

Fig. 5
Total carbondioxide for 24 hours (*Mangifera indica*)

of alcohol-injected leaves were measured, have been obtained. The ratios of total carbondioxide produced by the experimental and control sets before and after the injections have been calculated and compared in Table IX.

TABLE IX

Alcohol injected	Before injection			After injection		
	CO_2 values of control set in mgms.	CO_2 values of experimental set in mgms.	Ratio $\frac{CO_2 \text{ experimental}}{CO_2 \text{ control}}$	CO_2 values of control set in mgms.	CO_2 values of alcohol set in mgms.	Ratio $\frac{CO_2 \text{ alcohol}}{CO_2 \text{ control}}$
M. indica						
2 % ..	179·0	180·4	1·00	147·6	158·6	1·08
5 % ...	186·1	188·9	1·02	150·2	173·0	1·15
8 % ...	189·3	189·9	1·00	148·7	180·6	1·22
10 % ...	186·5	185·1	·99	150·8	161·3	1·07
15 % ...	181·2	180·8	·99	145·7	108·3	·73
A. tuberosum						
3 % ..	56·0	56·7	1·01	42·9	54·8	1·27
5 % ...	56·7	55·5	·98	46·2	58·8	1·29

The different values of $\frac{CO_2 \text{ experimental}}{CO_2 \text{ control}}$ of the above table have been reduced to unity and the corresponding values of $\frac{CO_2 \text{ alcohol}}{CO_2 \text{ control}}$ have been calculated. Thus all the values of $\frac{CO_2 \text{ alcohol}}{CO_2 \text{ control}}$ for the respective leaves become directly comparable (Table X).

TABLE X

Alcohol injected	Before injection	After injection
M. indica		
2 %	1	1·08
5 %	1	1·13
8 %	1	1·22
10 %	1	1·08
15 %	1	·74
A. tuberosum ...		
3 %	1	1·26
5 %	1	1·27

It is thus evident that the respiratory rate increases with increasing concentration of alcohol in the case of *M. indica*; the limit, however, is reached at 8 % alcohol beyond which carbondioxide production progressively decreases with increasing concentration of alcohol. Such a limit for the leaves of *A. tuberosum* is not possible to fix, as higher percentages of alcohol were not worked with in this case The results seem to be in general agreement with those obtained with the leaves of *Eugenia jambolana* reported in a previous paper.

The author thanks Dr. S. Ranjan for his kind help and guidance.

Reference

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ON THE ANATOMY OF SOME OF THE ASCLEPIADACEÆ

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(Received on February 7, 1940)

SUMMARY

1. Rubiaceous type of stomatal apparatus occurs in most of the plants investigated. Some possess secondary division walls in the subsidiary cells parallel to the pore, while others do not. *Stapelia variegata* Linn., however, exhibits the well-known Tradescantia type.

2. Oxalate of lime occurs in the form of solitary as well as clustered crystals.

3. The hairy covering consists of simple and uniseriate hairs, rarely unicellular hairs (*Stephanotis*). Glandular hairs have been observed in *Sarcostemma*.

4. The petiole contains a single, bicollateral and arc-shaped bundle in *Calotropis*, but it is accompanied by one or more smaller bundles at each and in *Leptadenia. Stephanotis*, *Ceropegia*, *Cryptostegia*, *Hemidesmus* and *Pergularia*.

5. Occurrence of laticiferous tubes, superficial development of cork, intra-xylary phloem in cell-groups or in a continuous ring at the margin of the pith, collenchyma in varying amount and assimilatory parenchyma in the primary cortex, and stone-cells in the same region are amongst the other prominent anatomical features.

INTRODUCTION

This investigation was taken up because the information on the anatomy of the Asclepiadaceæ is rather meagre. It was first proposed to study only the stomatal apparatus, because it is not dealt with in detail by the previous authors. Sabnis (1) describes the stomata of the species he studied, but makes no mention of the type to which they belong. Later on, it was found that the plants under investigation revealed other interesting anatomical features also. Hence the comparative anatomy of the petiole, stem and leaf has been studied. The following species have been investigated: *Caralluma attenuata* Wight., *Leptadenia reticulata* W. & A., *Stapelia grandiflora* Mass., *S. variegata Linn*, *Pergularia odorratissima* W., *Stephanotis floribunda* Brongn., *Sarcostemma brevistigma* W. & A., *Ceropegia spiralis* W., *Calotropis gigantea* Br., *Hemidesmus indicus* R. Br. and *Cryptostegia grandiflora* Br. All these have been recorded by one of the authors (Sayeedud-Din, 2, 3 & 4) either as growing wild or cultivated in Hyderabad.

Stomatal Apparatus

The stomatal apparatus has been found to belong mostly to the Rubiaceous type with certain variations. This type of stomatal apparatus without secondary division walls in the subsidiary cells is met with in *Pergularia*, *Cryptostegia* and *Hemidesmus indicus*, but in the last mentioned species one subsidiary cell is larger than the other. The Rubiaceous type of stomatal apparatus with secondary division walls in the subsidiary cells parallel to the pore is noticed in *Caralluma*, *Leptadenia*, *Stephanotis*, *Ceropegia*, *Calotropis* and *Stapelia grandiflora*. Stomata surrounded by several ordinary epidermal cells occur in the epidermis of the stem of *Sarcostemma*. *Stapelia variegata*, however, exhibits the well-known Tradescantia type of stomatal apparatus, being surrounded by four subsidiary cells. Jako (Solereder—5) describes a stomatal apparatus resembling the Tradescantia type in *Stapelia* sp. The authors' observations tally with those of Jako, and do not conform to Vesque's findings (Solereder—5). The stomata are deeply sunk in the epidermis.

Leaf—Slight striations in the cuticle are observed in *Leptadenia* and *Calotropis*; and well-striated cuticle occurs in *Hemidesmus* and *Cryptostegia*. Enlargement of the cells on the upper side of the leaf is noticed in *Leptadenia*, *Ceropegia*, *Calotropis* and *Cryptostegia*. This seems to be a device for water storage, as is suspected from the fact that the last three species which grow wild in Hyderabad inhabit dry situations.

Oxalate of Lime occurs in the form of solitary crystals in the stem and leaf of *Calotropis*, *Caralluma*, and *Stapelia* (both the species); and in the form of clustered crystals in *Stephanotis*, *Sarcostemma* (Fig. 14) and *Cryptostegia*. Solitary as well as clustered crystals occur in the stem and leaf of *Leptadenia*, *Pergularia* and *Hemidesmus*.

Laticiferous tubes occur in *Sarcostemma*, *Ceropegia*, *Calotropis*, *Stephanotis*, *Cryptostegia* and *Leptadenia*.

The hairy covering (Figs. 7—12) consists of uniseriate trichomes *(Leptadenia, Pergularia* and *Calotropis)*, and unicellular pear-shaped hairs *(Stephanotis)*, as well as 2-celled hairs *(Stapelia variegata)*. Uniseriate clothing hairs as well as glandular hairs occur in *Sarcostemma*.

Structure of the Petiole

The petiole contains a single bicollateral and arc-shaped vascular bundle accompained by one small vascular bundle at each end in *Leptadenia*, *Stephanotis*, *Ceropegia* and *Cryptostegia*. In *Pergularia* the single arc-shaped bicollateral vascular bundle is accompanied at each end by one, two or three small bundles. The petiole of *Hemidesmus* contains a single bicollateral and arc-shaped vascular bundle accompanied by two small bundles at one end and one small bundle at the

other end. The petiole of *Calotropis*, however, contains only a single bicollateral arc-shaped vascular bundle. Cells with dark contents have been observed in the primary cortex as well as a few in the pith of *Pergularia*. Stone-cells are present in the primary cortex in *Pergularia* and *Ceropegia* (Fig. 13).

Structure of the Stem

A characteristic feature is the presence of intra-xylary phloem. It occurs either in cell-groups or in a continuous ring at the margin of the pith The primary cortex contains collenchyma in varying amount in *Pergularia*, *Stephanotis*, *Hemidesmus* and *Leptadenia*. Assimilatory parenchyma resembling spongy tissue is found in the primary cortex of *Sarcostemma*. In the same plant stone-cells occur in the primary cortex as well as internally to the pericycle, and sclerenchymatous fibres are met with in the primary cortex (Fig. 14). In the primary cortex as well as in the pith of *Pergularia*, cells with gum-like substance occur in a broken ring. In the same plant, abundant development of vessels is found at four points, and in *Sarcostemma* on two opposite sides. Superficial development of cork has been observed in many of these plants.

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Explanation of Plates

Fig. 1. Leaf-epidermis.—*Cryptostegia grandiflora* R. Br.

Fig. 2. Leaf-epidermis.—*Hemidesmus indicus* R. Br.

To illustrate Rubiaceous type of stomatal apparatus without secondary division walls in the subsidiary cells.

Fig. 3. Stem-epidermis.—*Caralluma attenuata* W.

Fig. 4. Leaf-epidermis.—*Leptadenia reticulata* W. & A.

To illustrate Rubiaceous type of stomatal apparatus with secondary division walls in the subsidiary cells.parallel to the pore.

Fig. 5. Stem-epidermis.—*Sarcostemma brevistigma* W. & A. (Stomata surrounded by several ordinary epidermal cells.)

" 6. Stem-epidermis.—*Stapelia variegata* Linn. (Tradescantia type of stomatal apparatus.)

(all x 500).

" 7. Uniseriate trichome.—*Leptadenia reticulata* W. & A.

" 8. Pear-shaped hair on petiole.—*Stephanotis floribunda* Brongn.

" 9. Two-celled trichome.—*Stapelia variegata* Linn.

" 10. Ordinary hair on stem.—*Sarcostemma brevistigma* W. & A.

" 11. Glandular hair on stem.—*Sarcostemma brevistigma* W. & A.

" 12. Hair on corolla.—*Ceropegia spiralis* W.

(all x 120)

" 13. T. S. Petiole.—*Ceropegias piralis* W.
s. c, stone cells; v. b, single arc-shaped vascular bundle.

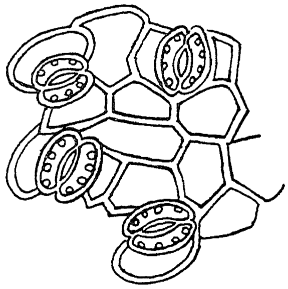
(x 120)

" 14. T. S. Stem.—*Sarcostemma brevitsigma* W. & A.
c, clustered crystals of Calcium Oxalate; chl., assimilatory parenchymatous cells; scl, sclerenchymatous cells; s. c, stone cells.

(x 120)

PLATE I

M. SAYEEDUD-DIN & M. R. SUXENA—*The Asclepiadaceae.*



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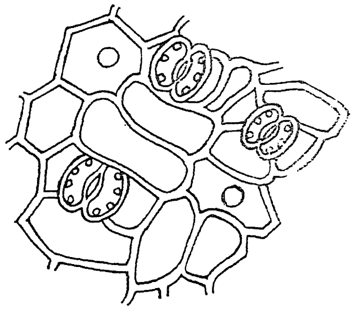

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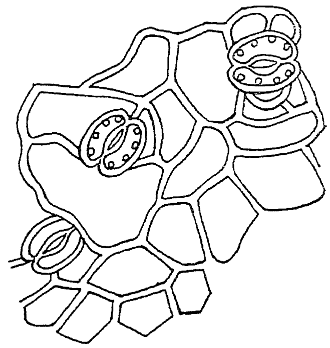

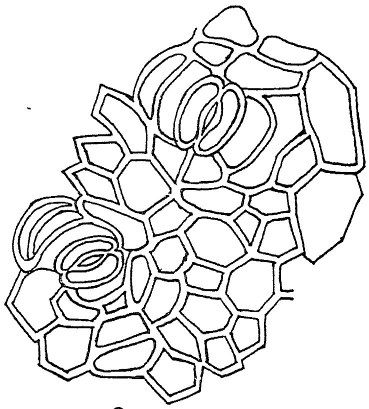

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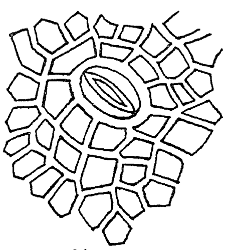

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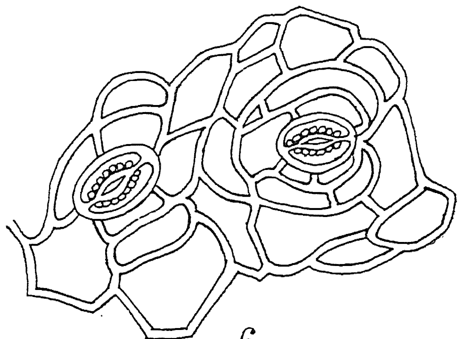

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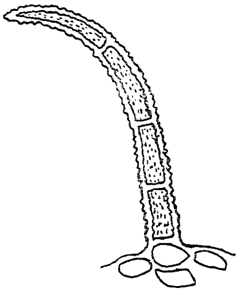
PLATE II

M. SAYEEDUD-DIN & M. R. SUXENA—*The Asclepiadaceae.*



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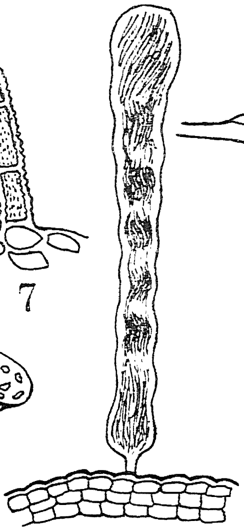

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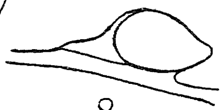

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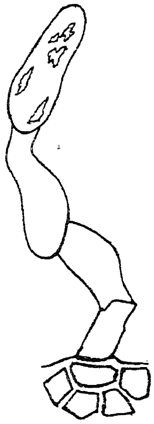

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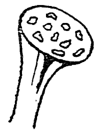

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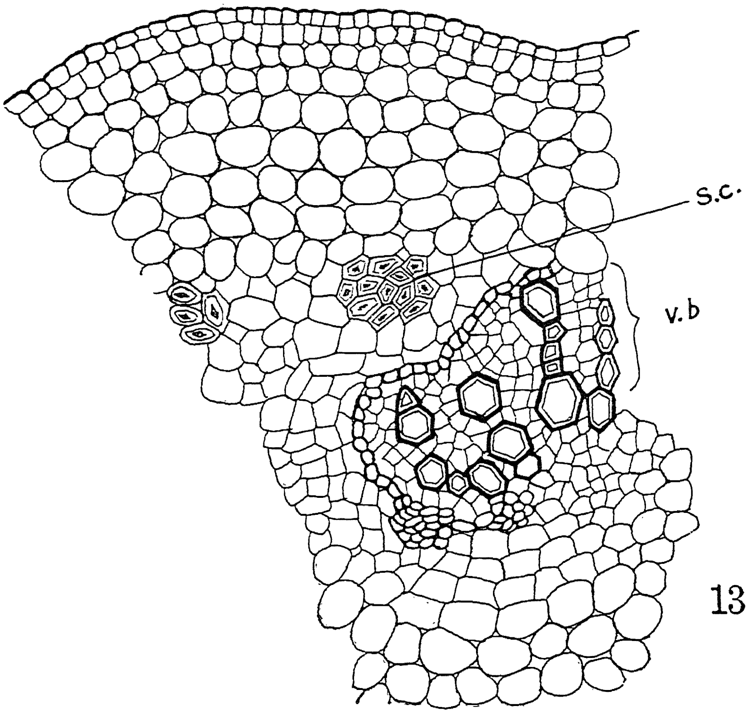

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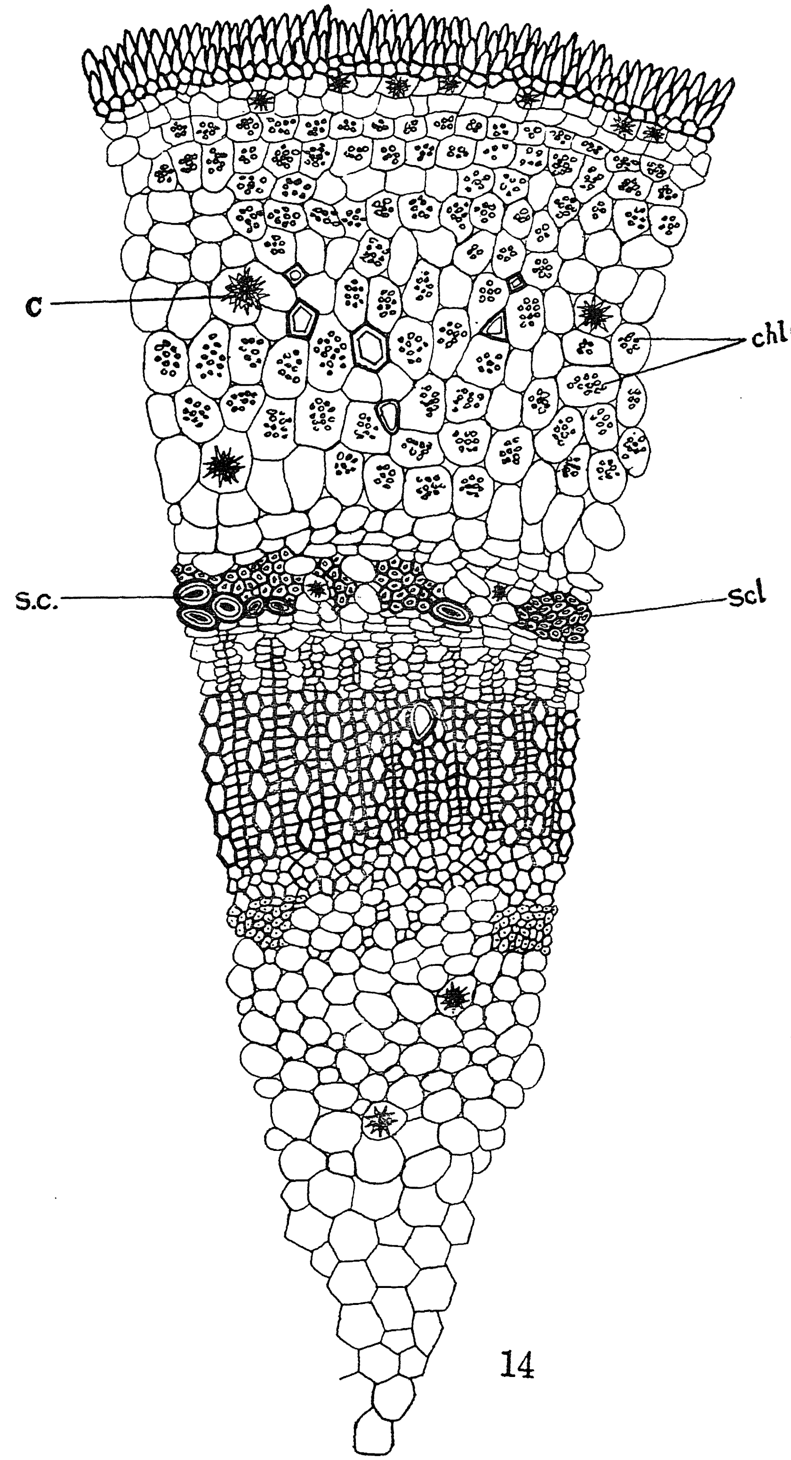

14

ON *HÆMOPIS INDICUS* N. SP. A NEW ARHYNCHOBDELLID CARNIVOROUS LEECH FROM KASHMIR

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(Received on April 1, 1940)

SUMMARY

In 1936 specimens of this leech were collected from pools and water channels in Pahlgam, Kashmir. The discovery of this leech in Kashmir is the first record of the genus *Hæmopis* from India. It is a carnivorous and cannibalistic form. The crop is packed with earthworms and leeches swallowed entire.

The alimentary canal of *Haemopis* differs from that of the ordinary blood-sucking leeches. The jaws are very weak, bear two rows of teeth (distichodont), the pharynx is long and muscular extending up to segment IX. The thin-walled crop is a slender, ***straight*** tube extending up to somite XVIII. There are no paired metameric cæca of the crop as are characteristic of the blood-sucking leeches. A pair of simple tubular cæca which arise from the posterior end of the crop extend up to segment XXII. The crop is followed by stomach, intestine and rectum.

The genitalia and other morphological details are in agreement with those of ***Hæmopis sanguisuga*** (Linnæus).

INTRODUCTION

In 1936 Prof. K. N. Bahl brought two specimens of a leech from Pahlgam (Kashmir), and kindly handed them over to me for identification and study. Next year on my visit to that place I collected a large number of specimens of the same leech and kept them alive to study their habits, and also made a few dissections which I fixed and preserved for a detailed examination of the internal anatomy. One of these specimens was sent for identification to Prof. J. P. Moore of the University of Pennsylvania, who referred it to the genus *Hæmopis.* The present species is an Arhynchobdellid leech belonging to the family Hirudidæ, sub-family Hirudinæ. This sub-family is divided by Blanchard into two tribes—DISTICHODONTA and MONOSTICHODONTA, according to whether they possess two rows or one row of teeth on their jaws. The tribe DISTICHODONTA includes three genera: *Hæmopis*, *Myxobdella*, and *Whitmania;* while the tribe MONOSTICHODONTA includes several genera: *Dinobdella*, *Hirudo*, *Limnatis*, *Hirudinaria*, and *Pœcilobdella*. Of the three Distichodont genera only two, i.e., *Myxobdella*, and *Whitmania*, have been recorded from India by Moore in the Fauna of British India (1927). Two species of the genus *Hæmopis* Savigny, from India were described by Kaburaki[5] in the Records of the Indian Museum 1921, but both these were found

by Moore to be synonyms of Indian species belonging to other genera, and he, therefore, concluded that the genus *Hæmopis* was not known from India. About the genus *Hæmopis*, Moore[7] writes, "No true *Hæmopis* is now known to occur in India. Several species have been reported but all have proved to be Monostichodont".

In 1886 Whitman [13] described *Hæmopis acranulata,* under the name *Leptostoma acranulatum* from China. In 1930, Moore[8] gave a fairly detailed account of *Hæmopis gracilis* from China.

The discovery of this leech from Kashmir is the first record of the genus *Hæmopis* from India. It differs in many respects from the known species, and there is enough justification for regarding this as a new species. This being the first Indian *Hæmopis* known to science, it is named as *Hæmopis indicus* N. Sp.

The specimens were narcotised in weak alcohol and fixed in 90% alcohol or corrosive sublimate. The dissections, made in normal salt solution, were fixed in Bouin's fluid and preserved in 75% alcohol.

The work was carried out in the Department of Zoology, University of Lucknow. I am indebted to Prof. K. N. Bahl for handing over to me the specimens of this leech collected by him and for finding time to read through and correct the manuscript of this paper. My best thanks are due to Prof. Moore for the determination of the genus and to Dr. Baini Prashad for the loan of necessary literature from the Library of the Zoological Survey of India.

Locality and Habitat

The specimens were collected from Pahlgam, Kashmir. These leeches are commonly known as burrowing leeches and inhabit swamps and shallow waters and are never found in larger and deeper waters. They are found in large numbers in shallow water concealed beneath stones and pieces of wood, to the undersurfaces of which they attach themselves. At some places they were found burrowing in soft mud near the sides of water channels. To a certain extent they are amphibious since they remain partly out of water and sometimes completely exposed to air. They even make short nocturnal visits on land, in search of food, not far away from water.

Diagnosis and Colouration

In living condition the body is exceptionally soft and flabby; the integument is perfectly smooth, there being neither papillæ nor tubercles to roughen the surface. The skin always remains moist and slimy on account of an enormous secretion of mucus. A mature specimen, moderately extended, measures 150 to 180 mm. in length and 12 to 18 mm. in width; while *Hæmopis* (*Leptostoma*) *acranulatum* Whitman, measures 120 to 150 mm. when extended and 70 to 80 mm. when at rest, and *H. gracilis* Moore, measures about 67 mm. The body is thick, for the greater part of its length, gently tapering at the anterior and posterior

extremities. The ventral surface is more or less flat and the dorsal is broadly arched, while annulation is very distinct throughout except on the lip. The posterior sucker is small and weak.

The body is of a dark colour in the living condition, without any definite trace of markings. The ground colour on the dorsal surface is olive or olivaceous brown. Some are very dark brown or even almost black on account of a very dense or nearly solid pigmented reticulum on the dorsal surface. The ventral surface is comparatively lighter, and sometimes marked by a few scattered flecks of dark brown pigment. There are no spots and stripes visible in the living condition and the margins also are not differently coloured. On preservation in alcohol for a few days, the pigment fades away, the reticulum becomes lighter, and a careful examination reveals a dense pigmented reticulum on the paramedian fields, which gradually thins out towards the sides. There is then seen a light brown stripe running along the whole length of the body in the mid-dorsal line. The colour patterns of *H. acranulatum*, and *H. gracilis* closely resemble each other, but they differ from that found in the present species.

SEGMENTATION

The limits of somites are determined on the basis of sensory annuli or the annuli bearing the segmental receptors. The segmental receptors, which are usually small and unelevated, look rather obscure and difficult to spot out in fixed specimens on account of contraction of the body, but in a fresh specimen they are easily seen even without the aid of a hand lens owing to the dark pigmented background. The annulus bearing the segmental receptors is regarded the first annulus of each segment (Whitman).[12] According to this method of counting:

somites I, and II, are uniannulate;

III, XXIV, XXV and XXVI, biannulate,

IV, V, VI, and XXIII triannulate; and

segments from VII to XXII, are quinquannulate.

The total number of annuli is 102. In *H. acranulatum* and *H. gracilis* there are 104 and even 105 annuli.

The body, inclusive of the posterior sucker, is composed of 33 somites (fig. 1) which are grouped into the following regions:

(*i*) The *cephalic* region is composed of a prostomial lobe and somites I to V. It is characterized by the inclusion of the anterior sucker, mouth, jaws and eyes, and by the absence of the nephridial pores. The five pairs of eyes are arranged, as usual, on the dorsal surface of somites I to V: the first three pairs lie on contiguous annuli, while the 4th is separated from the 3rd by one, and the 5th from the 4th by two annuli. The first pair of eyes is the largest and all the five pairs form an

arch on the head region. The eyes are not so easily discernible in the living as they are in fixed specimens.

(*ii*) The *preclitellar* region consists of *three* somites, VI, VII, and VIII. Segment VI is triannulate and the remaining two are completely quinquannulate. All the three segments possess nephridial pores at their ventral caudal ends.

(*iii*) The *clitellar region*, like other Rhynchobdellidæ is formed of *three* complete somites IX, X, and XI. There is no permanent clitellum, as is found in earthworms, but during the breeding season it becomes fairly prominent on account of the thickened layer of clitellar glands. Whitman could not determine the limits of the clitellum in *L. acranulatum*, and Moore had no specimens of *H. gracilis* with definitely developed clitellum. In a few large specimens of the present species the clitellum is seen to be very well developed, extending over the *three* somites (15 annuli) mentioned above. Although the clitellar region differs in colour and texture and is more or less swollen and smoother than the remaining segments, it seldom obscures the annulation. The genital apertures occur on the mid-ventral line of somites X and XI, the male generative aperture in somite X, and the female five annuli behind it in somite XI.

A pair of nephridial pores is present in each of these three segments.

(*iv*) The *middle* region is the largest in the body and consists of *eleven* complete somites, (XII to XXII). All these segments possess nephridia, and the posterior limit of this region extends to the last or the 17th pair of nephridial apertures.

(*v*) The *caudal* region is short and consists of *four* (XXIII to XXVI) incomplete somites out of which segment XXIII is triannulate and the remaining three are biannulate. Segment XXVI bears the anal aperture on its dorsal surface, the last three somites of this region serving as a peduncle for the posterior sucker.

(*vi*) The *posterior sucker* is composed of *seven* segments. All the seven annuli bear segmental receptors, and each annulus represents a segment.

The External Apertures

The *mouth* opening is placed in the centre of the funnel-like oral-chamber—the anterior sucker. The *anus* is of moderate size and is situated on the dorsal surface of the root of the posterior sucker, in the constriction separating the posterior sucker from the body in somite XXVI. The *apertures of the nephridia* consist of *seventeen pairs* of minute paired openings on the ventral surface of the body, each pair lying on the hindermost annulus of each somite from segments VI to XXII, just in front of the groove separating it from the succeeding segment. The *male* and the *female* generative apertures, as described above, are situated on segments X and XI respectively. They are median and ventral in position,

the two being separated from each other by 5 annuli. The male genital pore is in somite X, a2/a3 in the groove between annuli 30-31, and the female pore in somite XI, a2/a3 between annuli 35-36. A filiform penis, 10-11 mm. in length protrudes out of the male generative aperture in several specimens. In *H. gracilis* it is 1 to 3 mm. in length.

ALIMENTARY CANAL

The alimentary canal of *Hæmopis* (fig. 2) runs as a straight tube from the mouth to the anus It consists of (*i*) the *pre-oral chamber*, and (*ii*) the *buccal cavity*, (*iii*) the *pharynx*, (*iv*) the *œsophagus*, (*v*) the *crop*, (*vi*) the *stomach*, (*vii*) the *intestine*, and (*viii*) the *rectum*

The *pre-oral chamber* (figs 1B, and 2B) is a cup-shaped depression on the ventral aspect of the anterior sucker. The prostomial lobe and the first four segments of the head region form the roof of the oral chamber, while the circular rim of the sucker forms its outer boundary. (The oral chamber is well developed in blood-sucking leeches as it helps attachment on the prey and the sucking of its blood). At the base of the pre-oral chamber lies the *mouth* which is guarded by a thin, wide velum. The *velum* is formed of three triangular muscular folds which project from the walls of the oral-chamber and meet together to give a tri-radiate appearance to the mouth. It is well developed in the blood-sucking leeches, where it forms an almost complete partition between the pre-oral chamber in front and the buccal-cavity behind The mouth leads into the *buccal cavity* which is a very short chamber lying just behind the velum. This chamber accommodates the free anterior marginal folds of the pharynx, and its mucous membrane presents three small crypts, in each of which is embedded a pad-like small compressed jaw (fig. 2D). Of the three jaws, the median is dorsal while the other two are ventro-lateral in position. *Hæmopis* being a carnivorous leech, its jaws are very small and so vestigeal as to escape observation altogether. The jaws are really formed from the termination of the pharyngeal ridges from which they are scarcely differentiated. They are devoid of proper denticles (teeth), and are beset instead with two rows of blunt irregular, thin, cuticular plates, each series consisting of 15 to 20 small plates. In the two lateral jaws the plates are still further reduced in size and number. These plates are separate, partly detached and discrete at some places, while at others several of them are confluent. They are light brown in colour and are much reduced in size at the ends. The buccal cavity leads into the *pharynx* which is a slender fusiform muscular sac extending from somites VI to VIII. Its inner lining is raised into six main longitudinal folds or ridges which are well seen in a transverse section through the middle region of the pharynx, (fig. 2C). Of these folds one is dorsal, one ventral and the remaining two pairs are lateral in position. The two lateral pairs of folds are larger than the median dorsal and the ventrals. There are six smaller ridges alternating with the main ridges and all the

twelve ridges terminate in the three jaws. The pharynx and its ridges are lined internally by a thin layer of cuticle. (In *H. gracilis* the dorsal and the ventral median folds are larger than the two lateral pairs.) The muscle-layers that form the wall of the pharynx are thin and weak. There is an *outer longitudinal layer*, a *middle circular layer* and again an *inner longitudinal layer* of muscles. Of the three layers the middle layer of muscles is comparatively better developed than the other two. There is another set of muscles associated with the pharynx, in which the muscle-fibres extend from the wall of the pharynx to the body-wall; these are the *radial muscles.* All these muscles produce the sucking action which helps these animals in securing their food. The *salivary glands* (fig. 2E) are masses of unicellular pyriform glands, covering and surrounding the wall of the pharynx. They lie scattered in the space between the radial muscles of the pharynx and the body-wall. These glands are not so well developed in this species as they are in blood-sucking ones. Each cell is a gland by itself, and is produced into a long stalk or ductule. The ductules run forward in bundles along the wall of the pharynx to enter each jaw, in which they occupy an axial position. The papillæ on the flanks of the jaw, on which the salivary glands in the blood-sucking leeches open, are absent in this form, and the salivary ducts open instead into the groove (fig. 2D) placed between the two rows of the plates. The pharynx is followed by a slightly constricted region the *œsophagus*, which continues into the crop. The *crop* (fig. 2A) is a straight thin-walled tube extending from somite IX to the middle of somite XVIII. It shows no trace of metameric division and this feature is characteristic of carnivorous leeches, to which *Hæmopis* belongs. In segment XVIII there arise laterally from the caudal end of the crop, a pair of simple tubular thin-walled cæca which extend backward up to somite XXII. In *H. acranulatum* similar cæca are present, while in *H. gracilis* they are totally absent. The crop is capable of great distension and serves as a store-house for the swallowed food. It continues behind into the *stomach* (fig. 2A) which is a broad thick-walled U-shaped chamber placed in segment XVIII. The two horns of the U project anteriorly as two large pouches, and the belly of the U receives the crop at its concave anterior face and gives out the intestine at its convex posterior end. The wall of the stomach is produced internally into transverse folds which anastomose with one another. In *H. gracilis* the stomach is a simple straight tube. The stomach continues into the *intestine* which is a straight tube showing slight constrictions on both the sides. It extends from somites XIX to XXI. Its inner lining (fig. 2F) presents numerous folds resembling villi, that increase the absorptive surface of the intestine. The wall of the intestine is thinner than that of the stomach and is supplied with numerous blood-capillaries. The intestine continues into the *rectum*, which extends as a simple thin-walled tube from segment XXII to the anus, situated on the dorsal surface of segment XXVI. Absence of villi marks the beginning of the rectum.

Food

Hæmopis indicus is definitely a carnivorous and even a cannibalistic form. The reduced jaws and teeth are incapable of making cutaneous cuts. There is a wide velum, and the alimentary canal is not designed for suction of blood. It feeds on earthworms, leeches of its own species, and small leeches of other genera and species. Dissections of both fresh and fixed specimens showed the crop packed with earthworms and leeches. Large leeches were observed actually to pounce upon the smaller ones and swallow them entire. I have seen leeches and earthworms of an inconveniently large size being swallowed by *Hæmopis*. They are captured by their narrow anterior ends and are drawn in, apparently by *suction*, an action produced by the contraction of the pharyngeal muscles. The mouth which is very mobile becomes much distended during the process of swallowing. *Hæmopis indicus* seems to have a special liking for *Erpobdella octoculata*, [2] a leech which is very commonly found in the locality. At the time of narcotisation a well-fed *Hæmopis* vomits out its crop contents and as many as 6 to 12 leeches and earthworms have actually been seen thrown out through the mouth. In *H. acranulatum*, though the food is not recorded the structure of the alimentary canal appears to be of a carnivorous type, and about *H. gracilis* Moore writes that it is clearly not a sanguivorous leech but a predaceous one that subsists on water-worms, insect-larvae and probably other small animals.

The Reproductive Organs

Hæmopis, like other leeches, is hermaphrodite, each individual possessing both the male and the female generative organs. But the worms are not self-impregnating; cross-fertilization is effected during the copulation of two worms and insemination is reciprocal. The general arrangement of the various parts, though characteristic of the genus, exhibits certain peculiarities in this species.

(a) The *male generative organs*—The male generative organs (fig. 3) consist of (*i*) the *testes*, (*ii*) the *vasa efferentia*, (*iii*) the *vasa deferentia*, (*iv*) the *epididymes*, (*v*) the *ejaculatory bulbs*, (*vi*) the *ejaculatory ducts* and (*vii*) the *atrium*.

There are *ten pairs* of *testis-sacs* which are disposed in conformity with the segments from somites XII to XXI, and are arranged in pairs on each side of the nerve cord, each pair lying in the centre of the somite in which it occurs. Each testis-sac is a turgid spherical body full of seminal fluid. From the posterior surface of each testis-sac runs outward a short sinuous duct, the *vas efferens*, which connects the sac with the vas deferens of its own side. The two *vasa deferentia* are a pair of longitudinal tubes that lie on the outer sides of the series of the testis-sacs. They run forward in a sinuous course along the ventral body-wall, parallel to the nerve cord, about mid-way between the testis-sacs and the vesicles (bladders) of the nephridia. Both the vasa deferentia

are covered throughout the testicular region by a thick lobulated layer of unicellular glands. Anterior to the testes, in segments XI and X, they gradually lose their glandular covering, become more slender, and in the middle of somite X, in front of the 7th nerve ganglion, the vasa deferentia bend outwards, become abruptly enlarged and intricately convoluted, to form more or less tubular masses, the *vesicula seminales* (the epididymes). From the outer region of each epididymis emerges a glistening fusiform tube the *ejaculatory bulb*. It has a satiny lustre and is placed on the outer side of the epididymis lying more or less parallel to it in somite X. The anterior end of each ejaculatory bulb narrows down to a slender firm white tube the *ejaculatory duct*, the right or the left duct passing beneath the ventral nerve cord. It has muscular walls and a narrow lumen throughout. The ejaculatory ducts of both the sides bend inward for a short distance and in segment X, near the 6th nerve ganglion, open into a central body the atrium. The *atrium* is a greatly developed and highly muscular U-shaped, tubular organ, the two limbs of which lie in a dorso-ventral position mostly in somites X and XI and sometimes extend even in somite XII. The dorsal limb has at its free anterior end the bulbous prostatic thickening into which the ejaculatory ducts open. The bulbous part has a thick covering of several layers of unicellular glands, the *prostate glands*. Several ducts from these gland-cells open into the lumen of the bulb. The curved part and the entire ventral limb of the atrium together form the *penis sac*. The anterior terminal end of the ventral limb pierces the body-wall and opens to the exterior in segment X a2/a3, just beneath and ventral to the prostatic bulb. Within this is a coiled filamentous tubular *penis*, which when extended is seen as a conspicuous organ protruding through the male generative aperture (fig. 3).

(*b*) The *female generative organs*—The female generative organs (fig. 3) are developed harmoniously with the male organs. They are simpler than those of the male and are in the form of a U tube. The two limbs, like the atrial part of the male genital organs, are placed in a dorso-ventral position, the dorsal limb being smaller in diameter than the ventral limb. The dorsal part is made up of (*i*) a pair of *ovaries* enclosed in the ovisacs, (*ii*) the *oviducts* and (*iii*) the *common oviduct*; while the ventral limb consists of (*iv*) the *vagina* only.

The *ovaries* are a pair of minute filamentous bodies which are enclosed in the ovisacs, situated in segment XI, just behind the 7th nerve ganglion. From the base of each ovisac arises a slender *oviduct*, the right or the left oviduct passing beneath the ventral nerve cord. The two oviducts unite into a *common oviduct* in the centre of segment XI. The place of union of the two oviducts is embedded in a thick layer of unicellular *albumen glands*. Each gland-cell has a broad glandular base and a thin drawn-out duct, a number of which pass through the wall of the common oviduct to open into its lumen. The narrow common oviduct runs back to the tail end of segment XII and enters the extreme summit of the vagina,

which is a tubular pouch with muscular walls and a fairly wide lumen. The main chamber of the vagina is the *vaginal cæcum*, while the narrow anterior terminal end in segment XI, is known as the *vaginal stalk*, which opens to the exterior by a small orifice situated in the groove between annuli 2/3 of segment XI.

The genital organs of *H. acranulatum* Whitman (fig. 4) differ from *H. indicus* (fig. 3) in several respects :

1. The number of *testes* is not recorded.
2. The *epididymes* and the *ejaculatory ducts* (the ejaculatory bulbs) are placed more or less in one and the same line. The terminal part of the *seminal duct* (the ejaculatory duct) is very long and runs back along the dorsal side of the *penial pouch* (the penis sac) to enter the pouch near its hind end
3. The *prostatic bulb* is very small and insignificant, and it is situated at the hind end of the penial pouch.
4. The *ovaries* instead of showing the general arrangement characteristic of the genus, exhibit certain peculiarities. They do not lie near the anterior end of the vagina and like the prostatic bulb have shifted their position at the caudal end of the vagina.
5. The *common oviduct* part, covered by the albumen glands, is more compact.
6. The *vagina* is fairly long and is not very plainly differentiated into saccular and tubular parts.

In *H. gracilis* Moore the description of the genital organs is given without a proper representation of the different parts in the sketch. The number of testes recorded is *seven* pairs, and the remaining structures in the genital organs resemble those of *H. acranulatum* Whitman.

Moore [8] writes, "This species (*H. gracilis*) resembles *H. acranulatum* Whitman and differs from typical *Hæmopis* in having the oviduct continued straight cauded of the vagina instead of being doubled forward beneath it. This removes the ovisacs from the typical position in XIII to XVI or XV".

Hæmopis indicus, described in this paper, is very similar to the typical *Hæmopis* and its genital organs resemble in most of the details with those of *H. sanguisuga* (Linnaeus) figured by Scriban and Autrum [11] (fig. 296,) after Brandes, in Kükenthal Handbuch der Zoologie, Hirudinea.

ZOOLOGICAL POSITION AND DISTINGUISHING CHARACTERS OF : *Hæmopis indicus* N. Sp.

Order.—Hirudinea.

Sub-order.— Arhynchobdella.

Family.—Hirudidæ.

Ten-eyed, jawed leeches. They are from medium to very large size. Posterior sucker is very constant It includes aquatic, burrowing, and

amphibious forms. They are blood-suckers as well as predaceous and carnivorous. Complete somite is quinquannulate. Clitellum present. Colouration variable. Seventeen pairs of nephridia. The digestive and reproductive organs present considerable variation. They lay cocoons.

Sub-family.—Hirudinæ.

There is a great variety of forms. Most members of this sub-family live in swamps and are burrowers rather than inhabitants of larger and deeper waters. Some take solid carnivorous diet, most of them have large, papillated jaws, and are exclusively sanguivorous.

Tribe.—Distichodonta.

Jaws small and weak; *teeth mostly in two irregular* rows, few blunt, coarse, often vestigial or thin cuticular plates or absent. Chiefly predaceous. The distichodonts are in many respects the most primitive and in their predatory habits (feeding on worms, insect larvae and other smaller invertebrates, varied by an occasional meal of blood), their relatively simple digestive tracts, weak and often edentulous or even vestigial jaws, they stand nearest to the Erpobdellidae.

Their reproductive organs are complex.

Genus.—Hæmopis.

Integument peculiarly soft. Posterior sucker small, velum tumid, projecting into the oral cavity in the form of papillae. Jaws very small, distichodont (two rows of teeth) with very few imperfect cuticular plates incapable of making cutaneous cuts. Predaceous, alimentary canal simple, crop without metameric caeca.

Species.—Hæmopis indicus N. Sp.

(*i*) *Size*—80 to 150 mm. in length, 12 to 18 mm. in breadth.

(*ii*) *Integument* perfectly smooth, devoid of tubercles and papillae.

(*iii*) *Colouration* very dark owing to a dense dark brown or black reticulum.

(*iv*) Body composed of thirty-three segments which are divided in the following *six* regions :—

Cephalic I-V, *preclitellar* VI-VIII, *clitellar* IX-XI, *middle* XII-XXII, *caudal* XXIII-XXVI, and *posterior sucker* of seven segments.

(*v*) The male generative aperture is in segment X a2/a3, and the female aperture five annuli behind it in segment XI a2/a3. Seventeen pairs of nephridiopores from segments VI to XXII.

(*vi*) The *alimentary canal* is very simple. Three jaws are very small and weak, teeth in the form of blunt, irregular plates in two rows, 14 to 15 plates in each row. Pharynx is a muscular bulb, its inner wall is raised

into ridges. Crop is straight and simple without any metameric caeca. A single pair of long, slender, straight caeca arise from crop in segment XVIII, which run back up to segment XXII. Intestine is simple.

(*vii*) *Food.* The jaws are incapable of making cutaneous cuts. This form is predaceous, carnivorous, and even cannibalistic, feeding on leeches, earthworms, and insect-larvae

(*viii*) Reproductive system.

Ten pairs of testes from somites XII to XXI. Epididymes in segment X; *ejaculatory bulbs* arise from the epididymes, and *ejaculatory ducts* open into a large tubular *atrium*. *Prostatic bulb* covers the 6th ganglion, and *penis sac* is in segments X and XI.

A pair of *ovisacs* enclosing the ovaries in segment XI.

The *common oviduct* runs back and opens into a large tubular *vagina*.

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EXPLANATION OF PLATES

Fig 1. *Hæmopis indicus* N. Sp.

A. dorsal; B. ventral aspect.

an. anus; ***as.*** anterior sucker; ***e. 1.*** first and ***e. 5.*** fifth pair of eyes; ***g. p.*** male generative aperture; ***g. p.*** female generative aperture ***n. p. 1.*** first and ***n. p. 17.*** seventeenth pair of nephridiopores; ***p.*** prostomium; ***pen.*** penis; ***p. s.*** posterior sucker; ***s. r. o.*** segmental receptor organ; I-XXVI. the body segments.

Fig. 2. *Hæmopis indicus* N. Sp.

A. ***Alimentary Canal***; the pharynx opened out to show the pharyngeal ridges.

an. anus; ***br.*** brain; ***ca.*** crop cæcum; ***c. m.*** circular layer of muscles, ***cr.*** crop; ***int.*** intestine; ***n. e.*** nerve collar; ***œs.*** œsophagus; ***ph*** pharynx; ***p. r.*** pharyngeal ridges; ***rect.*** rectum; ***r. m.*** radial muscles; ***sal. g.*** salivary glands; ***st.*** stomach; ***v. n. c.*** ventral nerve cord; V-XXVI segments

B. ***Longitudinal section of the first eight segments.***

b. c. buccal cavity; ***b. r***brain; ***cu*** cuticle; ***j.*** jaw; ***o. c.*** oral chamber; ***p.*** prostomium; ***ph.*** pharynx; ***r. m.*** radial muscles; ***sal. g.*** salivary glands; ***v. n. c.*** ventral nerve cord.

C. ***Transverse section through the middle region of Pharynx.***

c. m. circular layer of muscles; ***cu.*** cuticle; ***ph. l.*** pharyngeal lumen: ***r. m.***, radial muscles;

D ***Jaw.***

j. jaw; ***j. m*** jaw muscles; ***s. o.*** salivary openings; ***t.***[1] and ***t*** [2], two rows of cuticular teeth.

E. ***Salivary Glands.***

s. d. Salivary duct; ***s. g.*** salivary glands.

F. ***Longitudinal section of the posterior part of the alimentary canal.***

cr. crop; ***ca.*** cæcum; ***i. f.*** intestinal folds; ***int.*** intestine; ***rect.*** rectum; ***st.***, stomach; ***s. f.*** stomach folds.

Fig. 3. Reproductive organs of *Hæmopis indicus* N. Sp.

In the male reproductive organs the terminal portion, *i.e.*, the last pair of testis-sacs and atrium are shown, ***d. e.*** ductus ejaculatoris; ***e. b.*** ejaculatory bulb; ***ep.*** epididymis; ***p. g.*** prostate glands; ***p b.*** prostatic bulb; ***p. s.*** penis sac of atrium; ***T. 10.*** Tenth pair of testis sac; ***v. e.*** vas efferens; ***v. d.*** vas deferens; ***v. n. c.*** ventral nerve cord.

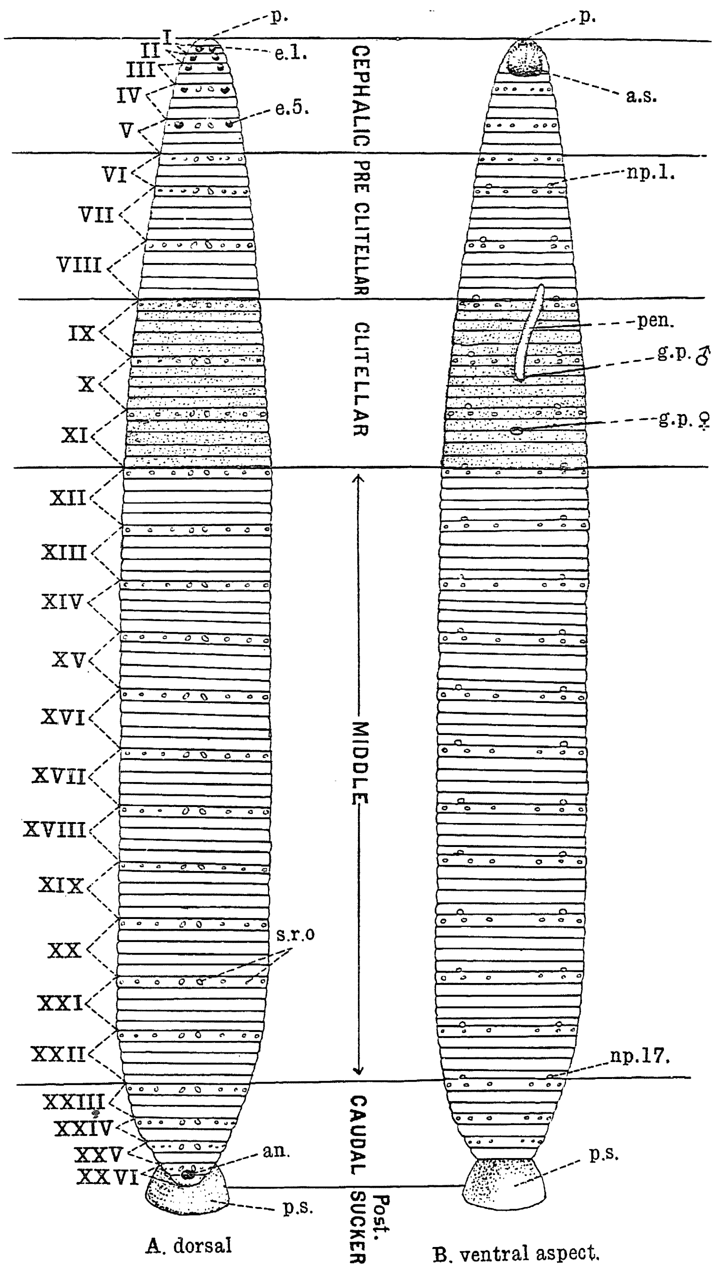
The female reproductive organs.

al. g. albumen glands; ***c. ov. d.*** common oviduct; ***ov. d.*** oviduct; ***ov. s***, ovisac; ***va. s***, vaginal stalk; ***v. c.*** vaginal cæcum; ***v. n. c.*** ventral nerve cord *6-7-8-9*. The nerve ganglia; IX, X, XI, XII segments.

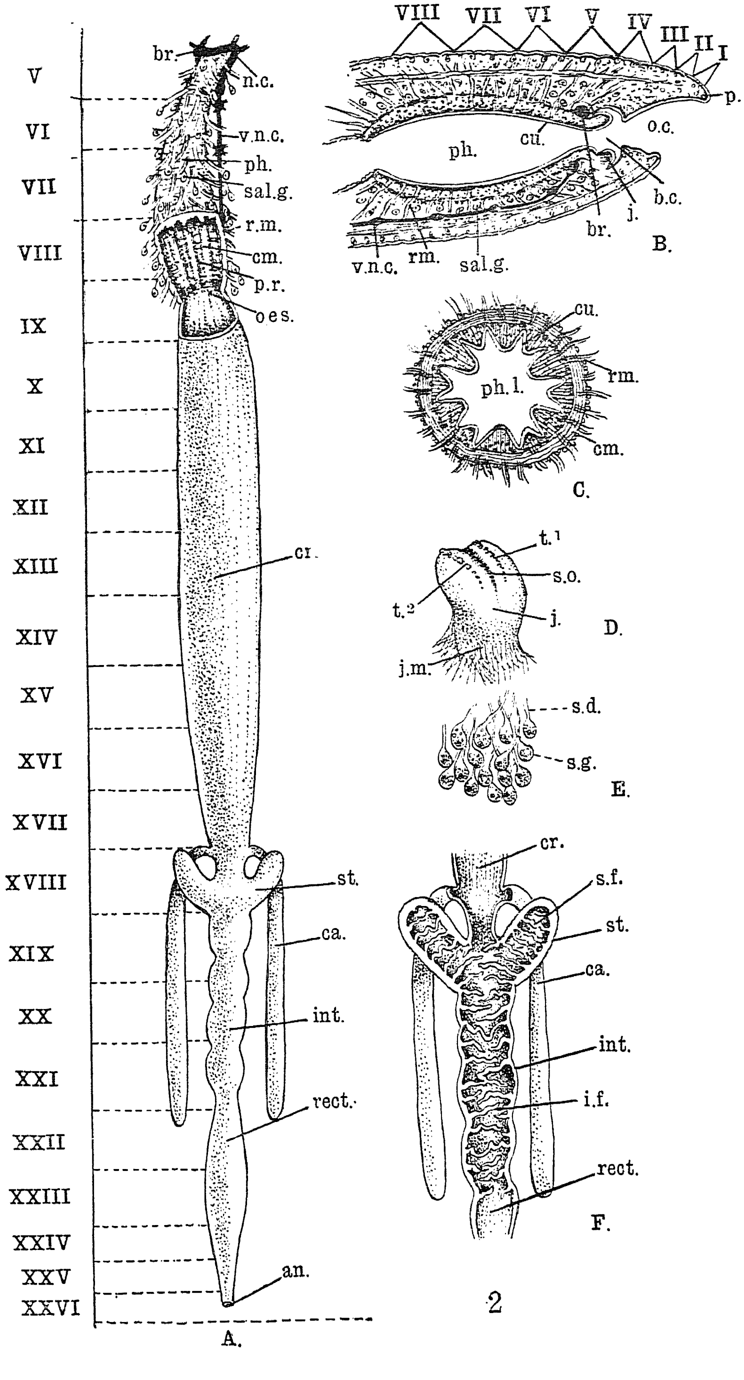
Fig. 4. Reproductive organs of *Leptostoma* (*Hæmopis*) *acranulatum*, after Whitman.

The male organs open between the 6th and 7th nerve ganglia (counting the subœsophageal as one); the female organ between the 7th and 8th. The ovaries have shifted their position from between the 7th and 8th ganglia to a point just in front of the 12th ganglion. The Vagina and penial pouch are extremely long. ***1-2 t.*** testes; ***v. d.***, vas deferens commune; ***v. s.*** vesicula seminalis (epididymis); ***d.*** ductus ejaculatorius; ***p. g.*** prostate gland; ***p.*** penial pouch (sacculus penis); ***ov.*** ovaries; ***al. g.*** albumen gland; ***c. ov. d.***, common oviduct; ***v.***, vagina; ***v. n. c.*** ventral nerve cord; 7 to **12** nerve ganglia.

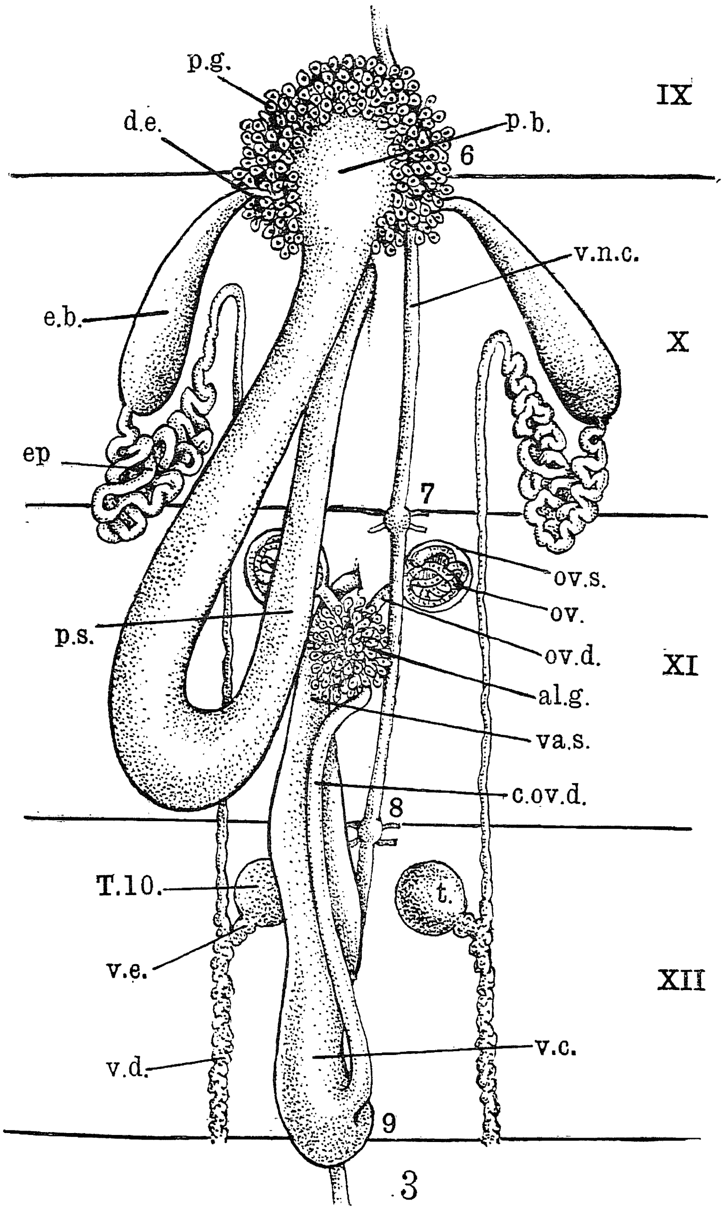
Hæmopis Indicus External Characters.



Hæmopis Indicus Alimentary Canal

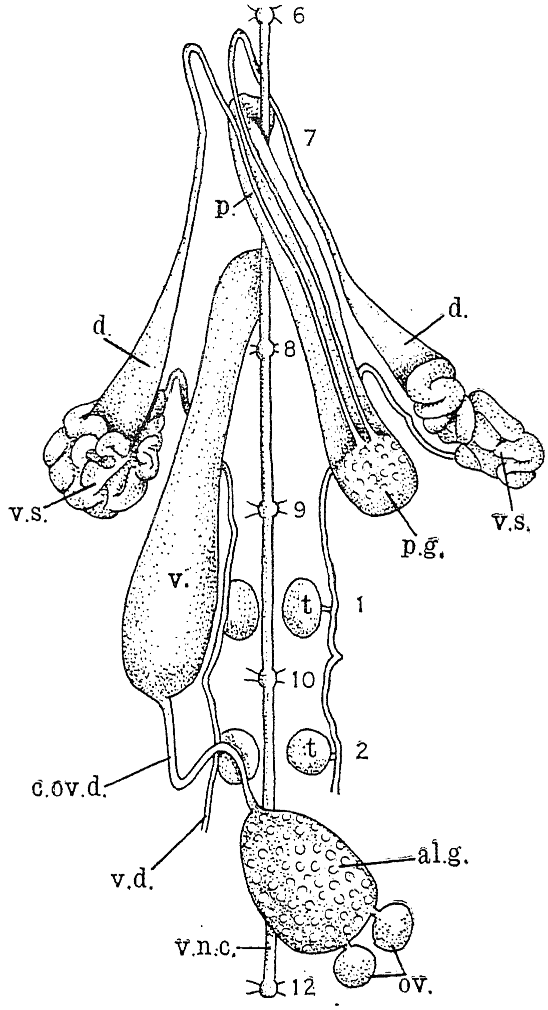


Hæmopis Indicus Reproductive organs.



3

Leptostoma (Hæmopis) *acranulatum* Reproductive organs



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References to literature, numbered consecutively, will be placed at the end of the article and short footnotes should be avoided. It is suggested that references to periodicals be furnished in some detail and in general in accordance with the standard adopted for the Subject Catalogue of the International Catalogue of Scientific Literature, *viz.*, name of author, with initials following (ordinarily omitting title of paper), year, abbreviated name of Journal, volume, inclusive pages.

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Every paper must be accompanied by *three copies* of a brief summary not exceeding 300 words in length.

A Proof will ordinarily be sent and the author is requested to return it at his earliest convenience.

THE
NATIONAL ACADEMY OF SCIENCES
INDIA

BUSINESS MATTERS

1940

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Judge, Federal Court of India, New Delhi

ANNUAL MEETING

The Tenth Annual Meeting of the National Academy of Sciences, India, was held in the University Hall, Delhi, at 11 a.m. on Saturday, the 22nd February, 1941. The Hon'ble Sir Maurice Gwyer, K.C.B., K.C.S.I., D.C.L., Chief Justice of India and Vice-Chancellor of the Delhi University, presided over the function. Dr. D. S. Kothari, M.Sc., Ph.D. (Cantab.), F.N.I., F.N.A.Sc., one of the General Secretaries, read the messages of good wishes from Universities. Dr. Shri Ranjan, M.Sc. (Cantab.), D.Sc. (State-France), F.A.Sc., F.N.A.Sc., one of the General Secretaries, then read the Report for the year 1940.

Lala Shankar Lall, the Chairman of the Reception Committee, read his welcome address. The Hon'ble Sir Shah Muhammad Sulaiman, Kt., M.A., LL.D., D.Sc., F.N.I., F.N.A.Sc., the President of the Academy, delivered his address. The Hon'ble Sir Maurice Gwyer then made a speech.

Professor A. C. Banerji, M.A., M.Sc., F.R.A.S., F.N.I., F.N.A.Sc., I.E.S., proposed a vote of thanks to the Hon'ble Sir Maurice Gwyer. Dr. Shri Ranjan then proposed a vote of thanks to the Delhi University.

SECRETARIES' REPORT

PRESENTED AT THE ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES, INDIA, ON SATURDAY, FEBRUARY 22, 1941.

BY SHRI RANJAN, M. SC. (CANTAB), D. SC. (STATE-FRANCE), F. A. SC., F. N. A. SC.

Annual report.

We have the honour to submit the following report on the working of the Academy during the period beginning from the 1st January, 1940 and ending with the 31st December, 1940.

The Ninth Ordinary Annual Meeting of the Academy was held on Saturday, the 13th January, 1940, at 3 p.m in the Mayo Hall, Allahabad. His Excellency Sir Maurice Hallett, K.C.S.I., C.I.E., I.C.S., Governor of the United Provinces and Patron of the Academy, presided over the function. Dr. Shri Ranjan, one of the General Secretaries of the Academy, presented the annual report.

Pandit Amaranatha Jha, M.A , F.R.S.L, Vice-Chancellor of the Allahabad University and Chairman of the Reception Committee of the Academy, read his welcome address. Sir Shah Muhammad Sulaiman, Kt., M.A., LL D., D.Sc., F.N.I., F.N.A. Sc., Judge of the Federal Court of India and President of the Academy, delivered his address. His Excellency Sir Maurice Hallett then made a speech, and gave away the Education Minister's Gold Medal to Prof. Mohammad Abdul Hamid Siddiqi, M.A., M.S., F.R C.S., D.L.O., Professor of Anatomy, King George's Medical College, Lucknow, for his paper on "The Genito-Urinary System of the Indian Ground Squirrel (*Funambulus palmarum*)".

Fellows and members.

We are glad to be able to record that the Academy has made steady progress both as regards its membership and its publications during the last twelve months. The Academy has now on its rolls 171 members who hail from every part of the country; of these 101 are elected Fellows and 5 Honorary Fellows. It is a great pleasure to record here that, during the year under review, Sir Shah Muhammad Sulaiman, Kt., M.A., LL.D., D.Sc., F.N.I., F N.A.Sc., was unanimously re-elected for the second time President of the National Academy of Sciences, India. During the full period of his office as President, permissible under our statutory limitations, he had devoted so much of his precious time and thought for the welfare of the Academy that it must record here its grateful appreciation.

Publications.

Our publications, Proceedings and Business Matters, which are the main indices of our activities, have progressed a step further. We have now been able to publish the physical and biological papers separately under these sections. But it has not been possible to publish them under

separate covers as planned ; the scanty resources at our disposal being insufficient to implement the scheme. Our Proceedings are on the exchange list of more than 170 Indian and Foreign scientific journals but during the last twelve months, due to War and censor, we have been able to exchange only with a limited number of foreign countries. During the year under report, we published four issues of the Proceedings containing 21 physical and 13 biological original papers, the total number of such papers communicated being 55. The articles published in the Proceedings have been highly appreciated and profusely quoted in scientific journals all over the world and have been abstracted in all the important Science Abstracts.

Finance.

The financial position of the Academy had never been quite satisfactory and the problem has become more acute now because of the World War. We are deeply grateful to the Government of the United Provinces for the grant which we have been receiving for the last several years, but this amount is not sufficient for the work the Academy has to carry out. We are obliged to repeat in this connection, what the Academy has been stating in previous reports, that in the first year of its existence the Academy of Sciences, U. P., as we were formerly known, received a grant of Rs. 4,000 per annum and it was in the hope that this grant would be made a recurring one that this Academy began to function. In subsequent years, however, owing to financial stringency, the Government reduced the grant to Rs. 2,000/- per annum, although the Academy has meanwhile attained the status of an all-India body. We hope that the Government will now be pleased to increase suitably the present grant and make it recurring. We are also deeply grateful to His Exalted Highness the Nizam of Hyderabad for his donation of Rs. 1,000 in 1938 but we cannot help regretting that the Academy has not received similar support from His Exalted Highness for the last two years. We hope that the Academy will not be deprived of His Highness's gracious support in future. We are grateful to the Allahabad Municipal Board for a donation of Rs. 237-8-0. We are also grateful to the Chief Saheb of Ichalkaranji for a donation of Rs. 100/- towards our building-fund. The Academy records its appreciation, and thanks to Mr. M. K. Ghosh, M. A., B. Com. (Lond.), Head of the Commerce Department, Allahabad University, for kindly auditing the accounts of the Academy. Auditor's report of the financial statement of accounts of the National Academy of Sciences, India, for the period from 1st April, 1939 to 31st March, 1940 is submitted at the end of the report.

Activities.

In 1940, we made a new departure from previous years. At the Annual Session in January, 1940 for the 1st time our Members and Fellows and many eminent scientists from different parts of India assembled at Allahabad and original papers were read and discussed. This was the first step towards the expansion of the sphere of intellectual and

cultural activities of the Academy. We are anxious to come into closer contact with other institutions by arranging, under the aegis of our Academy, combined meetings and conferences and thus provide intellectual and intersocial opportunities for cementing those contacts in a permanent manner. For this reason, we have organized an Ordinary Monthly Meeting of our Academy during the Indian Science Congress week, and this year the meeting was held at Benares. It is a matter of congratulation that this year too, notwithstanding the stress of economic conditions due to War, we are maintaining the same scheme. We hope that no serious repercussions resulting from War will adversely influence our progress. But at the same time we are sorry to say that the material well-being of the Academy, with which is intimately bound up its cultural activities, has not much improved. The paucity of funds has stood in the way of enlarging the activities of the Academy and taking up new programmes of scientific enquiry. For the same reason, we have not yet been able to organize a well equipped science library nor have we been able to take in hand the building scheme, although the necessity of a building where we can house the growing library and hold our meetings—is being increasingly felt. We would therefore again appeal, as on previous occasions, to all those who value the organization and progress of scientific education and research in India, for the well-being and uplift of the country, for generous financial support which alone could enable the Academy to perform all its functions efficiently.

The War, which started last year and which is continuing with unabated ferocity this year, has become a serious source of difficulty and even disaster in the economic life of mankind. In Western countries, increased grants and financial support are being given, both from Government and public funds to encourage special researches, helpful in winning War. Special grants are given to the Royal Society of London by the Government of Great Britain for special researches. At the beginning of the War our National Academy of Sciences, India, placed its resources at the disposal of the Government, but so far, unfortunately, the Government have not availed of the humble services of the Academy. We would beg to submit to the Government that if grants are available to us for certain specified branch of science, our Academy will be able to do, what little it can, in organizing researches of vital importance. We, however, note with gratification that one of our Fellows, Sir S. S. Bhatnagar, Kt., D.Sc., O.B.E., has been appointed Director of the Board of Scientific and Industrial Research.

Remarks.

We have now great pleasure to announce that the Education Minister's Gold Medal, kindly offered this year by Dr. Panna Lall, D Litt., C.I.E, I.C.S., Adviser to Governor, United Provinces, has been awarded to Dr. N. R. Dhar, D.Sc (London and Paris), F.I.C., F.N.I., F.N.A.Sc., I.E.S., Deputy Director of Public Instruction, United Provinces, Allahabad, for his paper on "Influence of Temperature and Light intensity on

Photosynthesis and Respiration and an Explanation of 'Solarisation' and 'Compensation' point".

It is a matter of gratification and the Academy felicitates on the confirment of Knighthoods on Brevet-Col. Sir R. N. Chopra, C.I.E, M.B, I.M.S., and Sir S S. Bhatnagar, O.B.E., D.Sc., and the title of C.I.E, on Mr. H. G. Champion, I F.S., C.I.E. The Academy also records with satisfaction the confirment of the title of Rai Sahib on Professor D. R. Bhattacharya, D.Sc. (Paris), Ph.D. (Dublin), F.Z.S., F.N.I., one of the Founder Fellows and Foreign Secretary of the Academy.

Of other distinctions conferred on the members of the Academy may be mentioned the Sectional Presidentship of the Indian Science Congress, held during the current year, by Dr. Shri Ranjan, M.Sc. (Cantab.), D.Sc. (State-France), F.A.Sc, F N.A.Sc., Prof. M. R. Siddiqi, M.A., Ph.D., F.N.I., F N.A.Sc., Professor Mata Prasad, D.Sc., F.I C., F.N.I, F.N.A.Sc., Prof. A. Subba Rao, D.Sc., and Mr. K. Ramiah, M.B.E

While organizing our growing library, the want of a librarian was keenly felt and we are glad to say that Dr. R. K Saksena, D.Sc. (State-France), F.N.A.Sc., a Fellow of our Academy, has consented to serve as its Honorary Librarian.

Dr G. T. Kale, D.Sc., who served the Academy as a Special Officer for a short period, has been appointed in Bangalore as a Librarian. The Academy records its appreciation of Dr. Kale's service. Mr. S. N. Bhattacharya, M.Sc., has been appointed in his place.

Lastly, we wish to offer our grateful thanks to the retiring President, the Members of the Council and to other Office-bearers of the Academy for their zealous and ungrudging help and co-operation.

Audit Report.

"We have audited the accounts of the National Academy of Sciences, India, for the year ending 31st March, 1940, and hereby certify that the accounts are properly maintained, and are correct to the best of our knowledge, information and belief." (Sd.) G. P. Jaiswal and Co, Accountants and Auditors, Registered Accountant, Johnstonganj, Allahabad, dated the 18th December, 1940.

WELCOME ADDRESS

LALA SHANKAR LALL
CHAIRMAN OF THE RECEPTION COMMITTEE

At the Anniversary Meeting held on February 22, 1941.

LADIES AND GENTLEMEN,

It is my pleasant privilege, on behalf of the Reception Committee, to welcome to Delhi the Fellows and Members of the National Academy of Sciences

The selection of this Imperial Capital as the venue of this gathering of eminent scientists from all over the country is not due to any mere coincidence. Your assembly here today but marks the natural consummation of tendencies of which the Academy itself represented the initial, though the most significant, fruition. For, taken as an event, the birth of your Association was just one more quantitative accretion to the bodies that deal with matters of erudition or utility. Taken, however, as a symptom, this Academy commemorates a notable land-mark along the path of our intellectual renaissance. For here you have both the incentive and the opportunity to pool all the creative genius in contemporary India for the service of mankind. Yours is by no means an original enterprise. The British Association in England, to take but one example, has pointed the way. But the creation in our midst of an analogous institution means for us a significant departure from our traditions of almost monastic endeavour which, practically *sui generis*, had been wont to be nurtured and developed in cloistered isolation. The movement, therefore, to which the National Academy of Sciences owes its origin represents perhaps the first attempt in this country at cooperative scientific research, at once synthetic and syndicated. Such a universal stimulus could not naturlly be circumscribed by the territorial limits or denomination of any one province. A venue with a wider radius was inevitable; and Delhi, with its Imperial associations and much wider focus, was bound one day to beckon you to its heart.

Then, of course, there is something personal in the selection of Delhi for your session. Sir Maurice Gwyer who inaugurates your Conference has an all India background with special roots in Delhi, where he adorns its University and presides over the Federal Court which serves as one of the more important rivets in the unity of our country. Sir Shah Sulaiman who presides over your Conference, having plumbed the depths of Relativity, has preferred translation from the parochial importance of Allahabad to the Imperial implications of Delhi, where he now fortunately finds the leisure to combine with his legal erudition the versatility of a great scientist.

With these two gentlemen here it is not in the least surprising that this year your deliberations should be convoked to Delhi. And for the success of their efforts in bringing you here our special thanks are due.

Finally it is only fitting that a movement of such vital interest and importance to this country should at some stage or other of its development come to be associated with the Capital of India. It is true that in democracies—and India is aspiring to a democratic constitution—the sources of power and culture have, generally speaking, little territorial community. But here the heritage of Delhi should make up for the short-comings of political psychology From time immemorial the name of this City has been woven into the pattern of our national legend and our national history. Amidst the ruins of this place you can still evoke the spirit of things and men, that lies at the very foundations of the poignant grandeur of our patrimony. From the Mahabharat to Prithviraj, from Mahmood of Gazni to the Mutiny, the pageant of our national existence is engraved on the debris of every wayside monument in Delhi. It is less, therefore, as a seat of Imperial Government than as a repository of some of the most sacred of our memories that Delhi is the most appropriate cradle for our intellectual revival. Let Delhi be a sort of scientific Kashi to which every mind anxious for enquiry may turn with hope, faith and profit. Indeed, the old observatory, better known as the Jantar Mantar, and the new Pusa already bear witness, in this direction, to something attempted and something achieved.

Of the destiny of your mission and the magnitude of your endeavour it is hardly necessary to speak. Whatever view one may have of our civilisation, the extent of comtemporary human misery can lead to only one belief—that the exigence of material needs has out-worn the resources of knowledge. On new discoveries alone, therefore, the material well-being of our race depends. In other words, human progress is the special responsibility of the scientists.

There is of course the other side of the picture. Scientific inquiry is always pregnant with the possibilities of worse monsters than the creature to be found in Mrs Shelly's Frankenstein. Destruction too lies in the limbo of scientific discoveries. Modern warfare is waged with inventions alone And in these anxious times, when civilization is rocking on its foundations under the seismic impulse of totalitarian ideology, the minds of most of us must re-echo the thoughts attributed to Edison in an apocryphical speech I heard the other day. "Earlier this evening," he said, "I talked with two school children. Tomorrow the world will be theirs. It is a troubled world, full of doubt and uncertainty. You say we men of science have been helping it. Are these children and their children going to approve of what we have done? Or, are they going to discover too late, that science was trusted too much, so that it turned into a monster whose final triumph was man's own destruction."

But it would be unwise to confuse cause with effect, and accidental distortion with a principle that is good. Science as such is free of all ulterior motive. Scientific

quest is fundamentally untainted by any thought of application. Such inquiry merely seeks knowledge, more knowledge, always knowledge. The purpose of such a quest is ever concerned with the ultimate benefit of mankind. For it is the wise who strive; and neither their edeavour nor their achievement is destined for mean ends You must, therefore, always seek for truth through more and greater knowledge, undeterred by any thought of whom it may hurt on the wayside by accident or by interested perversion of what you may hope to accomplish by a lift tune of devotion, sacrifice, and suffering As the Comte de Segur said, "peace is the dream of the wise: war is the history of man." You who are wise in seeking after knowledge should be content with your dream of peace. War cannot shatter that dream. It is on your perseverance, on your inflexibility of purpose, above all, on your own courage to admit no failure that rests the realisation of that dream. Even in a world throbbing with evil which the villainy of man has unleashed and which science has been perverted to arm, yours still is the future. For evil spends itself with satiation. You have still to heal. You have still to go on working for a better world. And in any case, in terms of temporal quantums, peace is longer than war. Your quest therefore still has to discover means to augment the sum total of human contentment.

The problem really is, to quote again from the fiction of Edison's life, that of adjusting the dual dynamos serving a unitary system. In the words attributed to him, "the dynamo of man's God-given ingenuity is running away with the dynamo of his equally God-given humanity." Edison himself is supposed to have propounded the solution. "Put those dynamos in balance," he is made to say. "Make them work in harmony as the Great Designer intended they should. It can be done. And then we need not be afraid of tomorrow..." Well, it is within your competence to regulate and balance both dynamos

Strictly speaking, perhaps, humanity as such is rather outside your province to adjust; and power in unsuitable hands will always tend to be abused. But you can diagnose and heal mental sickness begotten, whether of ambition, frustration, or inhibition. You can show that service is grandeur than conquest; that elements are more potent than armies; that knowledge is the only form of power which endures. Yours is the pride of creation—the pride of vicarious happiness born of personal sacrifice. Believe me, Gentlemen, of all the complex facets of mortal merit that are grouped under the name of chivalry, none sparkles with greater iridescence than the scientific effort with all its trials and its triumphs.

In the sphere of national economy the scientist has a vast field both for exploration and for reconstruction. Agriculture is just one example. Others are easy to quote. The entire romance of cotton, with its international upheavals and individual fortunes, from the coarse cloth of the poor to the finest cambrics and lawns that are at once the playthings and the necessities of the rich, has been conceived and perfected in science laboratories. The whole gamut of luxurious

sybaritism, with its uneven incidence ranging from personal bankruptcy to corporate effluence, is the work of scientific research. The perfumes that in turn add witchery to womanhood and haunt with their elusive fragrance, the memory of man; the synthetic stones and cultured pearls which have made accessible to the moderate purse the scintillating glamour of the wealthy; the brocades and georgettes and crepes that are at once the despair and the delight of sophisticated femininity—all trace their origin and growth to the germs of ideas incubated and fertilised in the scientific brain. The narrowing margin between territorial separations which the aeroplane, the wireless, and the television have done so much to bridge; the increasing victory of cure over disease; the very triumph of culture over primitive instincts—practically the whole range of human progress has for its motive force the dynamics of scientific inquiry and scientific solution.

But each method has its own point of saturation, leading perhaps imperceptibly but inevitably to exhaustion. It is science alone that revitalises time-worn techniques with the transfusion of new formulae. The very life-blood of industry comes from scientific research. New processes, new materials, new machinery, the very springs of national production flow from sources which scientists alone can tap. In short, alchemy may or may not be a mediaeval superstition. But this much at any rate is certain, that transmutations which in the old world would have worn the vestments of miracles have been achieved. The trend of modern economic expansion which has been built up on scientific enterprise justifies the faith that the ultimate happiness of mankind lies in the possibilities of scientific inquiry and scientific achievement.

ADDRESS OF THE PRESIDENT

The Dilemma in Physics

THE HON'BLE SIR SHAH SULAIMAN, KT., M.A., LL.D., D. SC., F.N.I., F. N. A. SC.

At the Anniversary Meeting Held on February 22, 1941.

I owe an apology for my presumptuousness in criticizing rather severely some of the modern fundamental concepts accepted by so many eminent theoretical physicists. Truth must be told howsoever bitter it may be. No theory can of course claim to be the final word on the subject. Indeed, all theories must in their very nature be mere speculations. When further data are collected, inconsistent with the existing theories and rendering them untenable, newer theories, which are closer approximations to truth, must replace the old. A complete exposure of the various inconsistencies underlying the modern theories is justified if destructive criticisms would provoke discussions, and a constructive substitute is offered for stimulating new research. Unless pointed attention is drawn to existing fallacies they are apt to be overlooked, and if in doing so a somewhat strong language is unavoidably used here and there it should be excused. I find consolation in the thought that such a great mathematician as Sir Arthur Eddington has felt compelled to say, "There is something radically wrong with the present fundamental conceptions of physics, and we do not see how to set it right."

THE DUALITY

Modern Physics is confronted with a formidable dilemma of an inexplicable duality, which has thrown it into a hopeless confusion, if not a muddle. Observations of light and matter show mutually contradictory phenomena either of a corpuscular or wave nature, but not simultaneously of both ; and the separate methods adopted to explain them are altogether irreconcilable. All efforts so far made to unify them have ended in utter failure. The only way to avoid the dilemma is by abandoning one's thinking power and shutting one's mind completely against all physical pictures. As we are reluctant to make a candid confession of our ignorance, the only alternative left is to have recourse to an abandonment of all physical concepts. The old terms, corpuscles and waves, are still employed, but without implying the meaning which they should connote. The current terminology is purely artificial, and the language used has no real physical significance. Terms like momentum and wave-length, energy and frequency, are separately by themselves understandable, but become mere catchwords when applied to the same entity. They

no doubt fascinate the mind, but they also keep it inextricably involved in complexities, without enlightenment. To a philosopher the physical explanations of the mysterious phenomena that are offered appear to be a mere make-believe and a pretence. One suspects that they are but a pretext for concealing the attitude of defeatism, which pervades all our concepts. Unkind critics see in the modern theories a reversion to the ancient methods of casuistry and quibbling. The classical concepts are ridiculed as old prejudices; but the modern prejudices are far more deep-rooted and difficult to eradicate. It seems to a layman that the new Science has been designed exclusively for an esoteric group of workers, initiated into its mysteries after a special training for accepting all postulates without question. The modern students are expected to have more a kind of blind faith in the new methods than a clear understanding of their physical implications. Those outside the charmed circle are characterised as diehards, belonging to an antiquated era, and wholly out of touch with modern developments. Any sceptic, who refuses to suspend his intelligence, is condemned as a heretic; any one who tries to free himself from the shackles of modern postulates is regarded as an ignoramus, steeped in classical prejudices. It therefore requires a great courage to stand up and publicly expose the numerous absurdities and self-contradictions in which the theoretical Physics abounds, in the faint hope that, although researchers, whose life's work has lain in this line, are not likely to be shaken, such exposure may appeal to the younger generation of scientists, who may not be so ready to accept everything on trust, and, unawed by authority, may like to examine for themselves the full implications of all modern postulates.

The Simple Fact

There is one simple and plain fact which is complacently ignored. The propagation of light and matter from one part of space to another can take place in two, and only two, possible ways. Either they are in the nature of vibrations that are conveyed by an all-pervading medium, or they consist of discreet units which are themselves bodily translated from one point to another. The assertion that no third way is conceivable cannot be challenged. Light comes to the earth from distant nebulae after traversing vast spaces for millions of years at a prodigious velocity. We cannot merely console ourselves by trying to believe that it is a result of some unknown microscopic processes. This is really a microscopic phenomenon on a gigantic scale, a great fact of nature which must be faced. It is clumsy evasion to suggest that as we do not observe the light until it actually reaches us, it is meaningless to ask how it is propagated. When observed on the earth it evinces the characteristics of corpuscles or vibrations, according to the nature of the experiment performed; and so it must be both, and yet is not both at the same time. The modern physicist does not pause to ponder over the implied inconsistency;

he talks of both without clearly understanding how the two are unified. In view of the numerous absurdities involved in a material medium, no physicist would now assert its existence, and yet he is never tired of talking of waves, and drawing analogies from material waves. But if a medium is admittedly impossible, all ideas of waves should have been abandoned *ipso facto*.

The Impossible Medium

The assumption of an ether for explaining the existence of waves caused innumerable difficulties which could not at all be surmounted. (1) Different ethers had to be postulated as different properties were required to explain different phenomena. The only variety of ether that survived for a time was the luminous ether as conceived by Huygens. (2) The first question was whether this ether should be assumed to be a gas, a fluid or a solid. Air and fluids were not found to transmit transverse vibrations, as they offer practically no resistance to distortion, and so the only alternative was to assume that the ether was a solid body stretching throughout space (3) But longitudinal vibrations were not observed at all, as no optical phenomenon indicated any vibrations normal to the wave front. Accordingly there was no option but to assume that either (a) the wave-length of the longitudinal vibration was infinite, in which case the ether would be absolutely incompressible, or (b) that it was nil or zero, in which case the ether would be contractile, *i.e.*, offering no resistance to compression. (4) If the ether were rigid, *i.e.*, offering resistance to change of shape, it could not be fluid and had to be an elastic solid. But if the ether has continuous extension throughout space, its bending without compressibility was unintelligible. (5) As there can be no special direction fixed in space the ether must be uniform in all directions, and so it must be capable of all possible vibrations; and yet it had only transverse and not longitudinal vibrations. If there were a perfect uniformity of the ether inside a crystal, it would not adequately explain polarisation and double refraction (6) Light has different velocities in different media. Mathematically, the velocity of a wave propagation in an elastic solid is proportional to the square root of its elasticity divided by its density. So the ether must have either (a) varying elasticity which would destroy its uniformity, or (b) varying density, which would make it cease to be incompressible, or (c) both, in which case both the difficulties would remain. (7) Light passes through transparent bodies. So the medium of its propagation must penetrate such bodies. But if the ether freely pervaded such bodies, then there was no satisfactory explanation why light should have different velocities in different bodies. (8) Further, if light is a mere vibration of the ether, and the ether penetrates through all bodies and pervades them, there was no reason why most bodies should be opaque to light. (9) Again, either the ether inside a body

is affected by the matter contained in it, or it is not. (a) If it is not, then all bodies ought to be transparent to light, as it is a vibration of the ether and not of matter. (b) If it is, then the ether inside the body should be affected in one way only, and the velocities of light of all colours should be the same; but they are not so. (10) Now if the ether were a vast store-house of energy, it might well have a spontaneous motion sometimes, but it has no spontaneous motion as the continuance of a source of light is indispensable. (11) If the ether were an elastic solid, the vibration once produced might well continue, even after the source of light is shut out. But there are no such subsequent oscillations. (12) If the ether were a solid medium, particularly if incompressible, even though elastic, then bodies moving through it ought to experience some resistance, but no resistance is noticed to the motion of heavenly bodies. (13) If light vibrations are to be only transverse, and not longitudinal, then mathematically the divergence of the light-vector would be zero. But for an elastic medium, such a zero divergence would mean rigidity without compressibility, making it impossible for any body to move through it. (14) Various other hypotheses were put forward from time to time, *e.g.* (a) the ether is like an elastic jelly, or (b) a turbulent fluid, or (c) that matter is like vortices or eddies in a stream. But all proved hopeless. (15) None of the apparently contradictory properties of the ether explained gravitation. (16) Another insoluble problem was the ether-drag or drift of the ether. If a material body moves through the ocean of ether, does it carry with itself the ether contained in it, or does it allow the ether to pass through it freely, so as to leave it behind?

Maxwell's Field

The electro-magnetic theory of light put forward by *Clerk Maxwell* attempted to get rid of some but not all the difficulties, by simply refusing to think of the ether as a material medium. Postulating the existence of an all-pervading medium, as waves cannot exist without it, he suggested that light consists of electro-magnetic waves caused by periodic disturbance in it. His great achievement, though anticipated by Kirchoff, was the discovery that the velocity of light was equal to the ratio of the electro-magnetic and the electrostatic units. Utilizing the great experimental laws and adding to them his conception of displacement current, he obtained his famous electro-magnetic equations. The luminous vibration is represented by an oscillating electric vector propagated in waves, and accompanied by a second magnetic vector, which also oscillates, both being normal to the direction of propagation Maxwell's electro-magnetic waves also require a medium for their propagation, but its properties are wholly mysterious. *Poincare* has shown that a mechanical explanation of the ether leads to an absurd result that, when in the absence of any electric field the medium is in equilibrium, the displacement due to elasticity would

be infinite. It is therefore not any real medium, but an abstract, purely hypothetical concept of an electro-magnetic field. All attempts to reduce the field to any real medium, an electro-magnetic ether, have hopelessly failed. The impossibility of the propagation of waves without a medium remains an insuperable obstacle, which is not surmounted, but evaded by pretending to believe that it does not exist, when in fact it should. Further, *Maxwell's* wave theory is absolutely incapable of explaining reactions between light and matter. Like every other wave theory, it is wholly inapplicable to a series of phenomena which unmistakably demonstrate the corpus cular character of light.

Manifestation of Corpuscles

Experiment shows that cavity radiation (*i.e.*, black body radiation containing all colours) depends on the temperature of the body only, and is independent of the material of the cavity. It is found that as the wave-length is decreased the energy rises up to a maximum, and then falls again with further decrease of the wave-length. The greater the temperature the more the maximum shifts towards the violet side. Theoretically, the energy of radiation for a given temperature should be proportional to the inverse fifth power of the wave-length, so that as the wave-length decreases the energy increases much more rapidly. Indeed, the energy would tend to infinity when the wave-length approaches zero. This is the notorious "violet catastrophe." The chief characteristic of a wave propagation is its continuous extension in space. If light were a disturbance in a continuous medium, then the vacuum can absorb an unlimited amount of energy, when the vibrations are those of continually growing rapidity. If a material body were placed in a closed region in thermal isolation, the ether will absorb the entire energy of the body and reduce it to an absolute zero—a state of immobility. A temperature equilibrium between the body and the cavity will be impossible. Experiment shows just the contrary. The energy does not continue to increase indefinitely with frequency, but a maximum is ultimately reached.

The Photo-electric effect deals another heavy blow to the wave theory. If the intensity of light falling on a metal plate is varied while the wave-length remains constant, the maximum velocity of the emitted electrons is independent of the intensity, which only affects the rate at which they are expelled. But if the wave-length of the light is varied, the velocity of the electrons changes inversely. There is also a minimum threshold frequency for each substance, below which no electrons are emitted. On the electro-magnetic theory the expulsion of the electrons is due to the strength of the electric field. If the intensity is doubled, the field strength would be multiplied by $\sqrt{2}$, causing the electrons to be expelled with greater maximum velocity. The Photo-electric effect is inexplicable on a wave

theory, which necessarily implies that energy is distributed continuously over a luminous wave, where there is no place for light quanta at all. Further, the light waves would pass over all the atoms, and there would be no reason why an electron should be expelled from one atom rather than another. Again, as energy will be obtained from the light falling on the atom, it will take time to acquire the requisite energy for expelling the electron. But no such time-lag is observed; electrons are expelled as soon as the metal surface is illuminated. Lastly, light waves ought to expand as they progress, and their energy should be gradually disseminated through space. The effect would be inversely as the square of the distance. But the Photo-electric effect shows that there is no diminution with the distance from the source. The result is the same as if discreet units of concentrated energy hit the atoms at long distances, it being immaterial how far they had previously travelled. It is like a shell full of explosives which has the same destructive effect no matter how far from the gun it bursts.

Arthur Compton has discovered that X-rays falling on electrons behave exactly like a swarm of material particles, collide with the electrons and are deflected like billiard balls. Energy and momentum are partly transferred to the electrons by the encounter, so that the frequency of the scattered photons is decreased and their wave-length increased. *Compton* observed the change of wave-length at various angles of scattering for certain wave-lengths, and also measured the recoil of the electrons. He established that the laws of the conservation of energy and momentum are satisfied in the impact. He further found that the speed of the recoiling electrons depends on the frequency of the light and not on its intensity. It is obvious that when the tracks of individual electrons are observed they appear to be corpuscles.

Raman has observed scattered light when passed through a liquid, and noticed not only the same frequency but also higher and lower frequencies. The differences correspond to the frequency of the scattering molecules, which either absorbed energy from or transferred energy to the photons. The exchange of energy in the collisions between photons and molecules was of just those quanta which had the frequency of the molecules, demonstrating that photons consist of separate concentrated units.

The very conception of photons (light quanta or corpuscles) assumes the existence of discreet units. Different kinds of photon possess different quanta of energy, and concentrated energy is a purely corpuscular characteristic. Photons possess momenta—a concept incompatible with waves. They are known to possess angular momenta (Spins), which would represent rotations of distinct, separate units. The essence of waves is their ability of superposition; collision and scattring of photonic waves would be absurd. Concentration of waves in points is unthinkable. The propagation of real waves would require a material medium, which owing to innumerable difficulties is completely denied. Waves would spread out as they progress;

light quanta individually do not. There exists no explanation how an electromagnetic field is created. It cannot be seriously denied that when we observe the behaviour of individual photons they exhibit their corpuscular character.

Till very recently matter was given all the corpuscular characteristics. We estimate the number of atoms in the various classes of molecules, the number of atoms in a gramme, the mass of an atom, the radius of an atom, the distance between two atoms, the number of electrons in the various elements, the mass of the electron, the mass of the nucleus, the masses of the position, the neutron and the neutrino—all well-defined. Dalton's Atomic Theory and also the Kinetic Theory of Gases bring to prominence the corpuscular character of matter.

We observe the tracks of electrons in a Wilson Cloud Chamber. The α and β particles emitted by radio-active substances cause the condensation of water vapour into minute droplets, arranged along definite tracks, when they pass through a supersaturated water vapour in a chamber. Their photographs show the existence and continuity of their tracks as if a stream of discreet particles has moved across. Their masses and charges are determined by their deflection in electric and magnetic fields. Now and again we see sharp and large deflection of the tracks pointing unmistakably to the collision between the particles and the nuclei of atoms. Photographs of the deflections of the particles and the nuclei of oxygen and nitrogen have been obtained, and it is also established that sometimes a proton is knocked out by the impact. Sometimes a proton striking a nucleus knocks an electron out of it.

When a stream of electrons falls on a sheet of glass lightly powdered with zinc sulphide crystals, faint sparks (scintillations) appear all over it, each scintillation being produced when a single electron hits the screen. This demonstrates that electrons travel like a shower of rain—a swarm of discreet units. All these show unmistakably that photons and material particles have separate individualities.

The Great Puzzle

There remain at the most three phenomena, one of which, polarisation, though causing puzzle, can be explained on the corpuscular concept also, but the other two, *interference* and *diffraction*, which in essence are really only one, are unfortunately believed to be absolutely irreconcilable with a corpuscular structure.

The phenomenon of interference shows that monochromatic light beams from two separate sources produce successive bright and dark bands, indicating that these beams interfere with each other. It is pointed out that this can be explained by assuming that the crests of one and the troughs of the other cancel out and produce darkness. It is firmly believed that two corpuscles cannot destroy each

other. The phenomenon of diffraction is in essence the same as interference, because both depend on a phase difference. Successive bright and dark bands can be obtained if light strikes a straight edge; and successive bright and dark circular rings are obtained if light is passed through a small pin-hole or circular aperture. Zone plates and Diffraction gratings magnify the effect because they contain a large series of successive small apertures.

Davisson and *Germer* showed in 1927 that a stream of electrons possessing the same velocity and sent against a nickel crystal produces phenomena similar to that produced by X-rays. Later, *G. P. Thomson* found that a narrow pencil of electron rays of moderate energy passed through an extremely thin metallic film on to a photographic plate produced an image consisting of a central spot with circular rings round it due to the diffraction of the electrons by the small crystals of the metallic film. More recently the diffraction of whole atoms has been observed by *Dempster*, and of heavier atoms by *Stern*, by the method of crystal reflections.

The Deadlock

Neither the old corpuscular theory nor the wave theory can adequately explain these two sets of phenomena. No comprehensive theory which would include both exists at present. In sheer despair all physical concepts have been completely abandoned, and we are asked to assume that light and matter are both corpuscles and waves in character; but we are warned against trying to think out how they can be related. It is boldly asserted that these two aspects are complimentary, although even the slightest reflection would convince one that they are absolutely contradictory. Obviously a thing cannot be both a particle and a wave at the same time, as the two concepts are entirely different. Yet simultaneous use of these two contradictory concepts is made without any hesitation. Corpuscles can mean nothing else but separate and discreet units. Waves must necessarily involve continuity of structure. In modern Physics we freely talk of photons, connoting nothing else but light-corpuscles, and yet there is no compunction in talking of them vaguely as a wave, and stating in the same breath that the so-called wave has of a certainty no physical character whatsoever. If an inconvenient question exposing the untenability of the position is put, the question itself is characterized as meaningless, forgetting that the fictitious waves themselves have neither any meaning nor sense. In spite of all the casuistry that is perforce adopted, the plain fact remains that these two aspects are irreconcilable. We have arrived in a *cul de sac*, from which there is no further progress. Physicists have recouse to entirely different methods of the Wave theory and the particle Mechanics according to the experiments they wish to perform. We complacently use two diametrically opposed ideas according to circumstances and pretend not to do so.

If there were a frank confession that our knowledge has not advanced far enough to comprehend the true structure of light and matter, the attitude would be perfectly intelligible, as human perception cannot pry into the innermost mysteries of Nature. Instead, all sorts of subterfuges are resorted to, which introduce a hopeless confusion into theoretical Physics. In supersession of all physical pictures a highly artificial mathematical apparatus is set up, and we are asked to work with it and forget that it has no physical significance.

Quanta

First came *Planck's* assumption that the ratio of the energy to the frequency is a universal constant, a fixed angular momentum. Now, energy is a corpuscular concept, while frequency is a purely wave concept. These have been arbitrarily related without any attempt to explain how these two contradictory concepts can be connected. The inconsistency of defining the energy of a corpuscular photon in terms of the frequency of light, a notion borrowed from the Theory of Waves, which is left unexplained, is only too obvious. According to Maxwell's Electro-magnetic theory, a planetary atom would emit radiation continually as it moves round its orbit; resulting in a progressive diminution of its motion. But Neils Bohr arbitrarily assumed that electrons describe only a limited number and not all possible orbits; he further assumed that while moving in their orbits they emitted no radiation, in absolute contradiction with acceleration-wave; and then still further assumed that they suddenly change their orbits without traversing the space between them, a contradiction in terms, and that in the process they emit part of their energy in the form of radiation. The beautiful picture of a perfect miniature solar system has been marred by imposing on the planet electrons an arbitrary "quantised" motion. It is an essential part of *Planck's* and *Bohr's* theories that intermediate values of energy do not at all exist, so that the atoms must suddenly and timelessly change from one energy state to another. This necessitates a discontinuity in the levels of energy. Again, the wave train which it sends out is fairly long, so that emission must require an appreciable time. Intermittent emission necessitates discontinuity in the flow of radiation, and yet continuity of radiation waves is asserted. There is an inevitable contradiction in asserting that energy is emitted in quanta, and yet the emission of each quantum is spread over a time interval. If the train is continuous, the question what energy can the atom possess during the interval of the change is not answered, but evaded. The conception of a sudden and instantaneous jump is unintelligible. Being unable to get rid of the absurdity, the modern physicist hides his discomfiture by proclaiming that the question itself is meaningless, as we should not ask what energy the atom has unless we can actually measure it. This resembles the old casuistry. When two states

are contemplated, the passage from one to the other ought to be capable of contemplation, quite irrespective of actual measurement. Such a futile dodge, no matter how much we may try to camouflage it, cannot satisfy a searching mind. The very essence of waves is their power of superposition; waves can overlie on the same point of space, and pass through undestroyed. But two electrons cannot occupy the same space. Paulis' postulate of the Exclusion Principle states that two electrons cannot occupy the same orbit in the same state, that is to say, they cannot be the same kind of waves—this undermines the very conception of waves and destroys their chief characteristic.

Associated Waves

De Broglie has extended this idea to matter and assumed that material corpuscles are somehow or other "associated" with waves. No effort is made to suggest how this curious association can exist. The very use of the vague word "associated" was intended to hide the otherwise patent fact that the assumption is self-contradictory. The assumption is made without any real justification, as in no experiment a single particle is ever observed to show the properties of a wave. No answer is given to the question: what is the exact significance of the dualism which we are asked to accept as a fact of Nature? The vagueness of the relation of energy and frequency is the greatest difficulty of Modern Physics, which cannot be surmounted. A connexion is invented between the mechanical properties of matter, momentum and energy, and its characteristic wave properties, wave-length and frequency; but we are to accept its universal truth without any thought of reconciling the contrary nature and without any attempt to consider how waves can accompany matter. I am far from suggesting that it does not work well in practice. I only wish to emphasize that we have not got to the bottom of the mystery, and falsely pretend ignorance of our failure. *De Broglie* imagined a corpuscle to be a group of waves or a wave packet, *i.e.*, a limited portion of a train containing a number of crests, which moves with the group velocity. The idea is illustrated by reference to water waves, sound waves or elastic waves in a metal; but all these are waves in a medium, whereas no medium is postulated by de Broglie. The analogy is therefore altogether incomplete. The hollowness of the assumption, when no medium can exist, needs no further comment. Although material corpuscles are represented by waves, there are no real waves at all, not even of energy. Unless one has a recourse to quibbling, one cannot withhold the admission that the reason why the two aspects, the corpuscular and the wave aspects, of light and matter exist is not at all known, and all attempts to merge them into one single synthesis has not succeeded so far.

Matrix Mechanics

Heisenberg has adopted artificial methods to do away with all physical pictures. He starts with the assumption of the empirically established law that for a particle the product of the momentum and the wave-length is a universal constant. $p.\lambda = h$. There is an inevitable self-contradiction in the assumption, which is conveniently skipped over. Momentum can be associated only with the corpuscular character, whereas wave-length is purely a wave nature concept. How can they be reconciled ? No explanation is forthcoming for their true significance. All physical ideas are discarded, and the mathematical relation is accepted as a law of Nature. *Heisenberg* next assumes the law of Optics which governs the resolving power of optical instrument $\triangle x = \frac{\lambda}{2 \sin\alpha}$, and applies it to a photon scattered by an electron and passed through a microscope to the eye for which the uncertainty in the recoil suffered by the particle is given by $\triangle p_x = \frac{2h\nu}{c} \sin\alpha$. This is a curious admixture of different ideas with a characteristic contradiction underlying the relation, as simultaneous use has been made of deductions from corpuscular and wave theories of light. The idea of the resolving power of an instrument has been joined with that of photons colliding with particles and recoiling, and the serious inconsistency naively ignored.

Heisenberg has evolved the so-called Uncertainty Principle that it is impossible to find out both momentum and position of a particle simultaneously. It is explained that the act of observing one co-ordinate necessarily causes a change in the conjugate co-ordinate, so that the accuracy of one produces an uncertainty in the other. But do we ever observe the position of an electron ? We observe its track, but that is quite a different thing from its instantaneous position. As to the so-called wave-length of an electron, it is admittedly meaningless as a physical phenomenon. It has never been seriously suggested that any one can observe the wave-length of a single electron; the supposed wave-length is merely measured from the diffraction halo of a swarm of electrons. What then becomes of the Uncertainty Principle as applied to an electron ? Now to make sense, it can only mean that in practical measurements both the position and the velocity cannot be determined simultaneously; this is trite, as obviously the method of determining one must be quite different from that of determining the other. The assertion really confuses practice with theory. The question in theory is not only whether we can determine the exact values experimentally, but also whether they do not exist simultaneously. It may equally well be asserted that it is impossible to determine exactly the value either of velocity or position by any experiment, as an error of observation must always enter. Our accuracy can never reach beyond some limit. Again, if it were a question of observation only then the error can be both positive and negative, and

even with a large number of observations the result would still necessarily be inexact. But although starting with the impossibility of measurement, the line of reasoning suddenly turns back, and it is asserted that the uncertainty is not one due to any error of observation, but is inherent in the nature of things. But when the method of proof is scrutinized it turns out that the whole theory is based on the assumption of the existence of discreet units.

Heisenberg and later *Born* and *Dirac* have attributed to the mechanical co-ordinates the characteristics of matrices and applied to them the laws of generalized dynamics. Thus on the top of the fundamental postulate of quanta a highly artificial structure, which has no claim to any physical significance, has been built up by identifying dynamical quantities with matrices. In this way, a new science of Quantum Mechanics has been developed, yielding a set of equations, containing an imaginary quantity, the square root of minus one, without any indication whatsoever of the physical implications of the processes involved. To derive a wave-equation, for the components of momenta, p_x, p_y, p_z, are substituted the operators $\frac{h}{2\pi\sqrt{-\iota}}\frac{\delta}{\delta x}$, $\frac{h}{2\pi\sqrt{-\iota}}\frac{\delta}{\delta y}$, $\frac{h}{2\pi\sqrt{-\iota}}\frac{\delta}{\delta z}$. To make things still more mystical, for energy E is substituted the operator $\frac{h}{2\pi\sqrt{-\iota}}\frac{\delta}{\delta t}$. One fears that what is a mysticism in these days may perhaps become a subject of amusement for the future generation.

Heisenberg's Uncertainty Principle would not be a new philosophy but a necessary deduction of the quantum postulate, if we restrict the theory to the practicability of measurement. But a genuine theory should not depend on the accuracy of measurement. Of course, while one is trying to observe the position of a body one would not in that process be measuring its velocity; but is that a justification for saying that it cannot have position and velocity at one and the same time? Attempt is made by Heisenberg to say that we must confine ourselves to observables only and not even contemplate the necessary implications of accepted concepts. The human mind can conceive how things can become observables, though unobserved. The distinction is at best crude, unless we put aside our intelligence completely. Should we deny the existence of a core inside the earth or the sun because we do not observe the same? The unaided human eye cannot simultaneously observe two sources of light in opposite directions; then are we to deny their simultaneous existence? If without the help of any artificial contrivance one is not able to see the two sides of a picture at the same time, must he then believe that when one side exists the other does not? Again, we are supposed to measure wave-lengths by means of interference fringes; we never measure frequency at all. Yet physicists are never tired of talking of the unobservable frequencies. They are not prepared to abandon the conception. No experiment has yet measured the amplitude, why then talk of it? If we measure only total heat, and not molecular

energy directly, why should we talk of such energy? As to the wave itself, the wave of probability or chance, is it observable? If not, abolish it. Has any one observed the neutrino? Why should one postulate it? Has any one observed the train of a single electron or its wave-length or frequency? Why are they contemplated? Even a perfunctory examination will show that in theoretical Physics we must assume many things and contemplate many possibilities which are not directly observed. To assert that we can confine attention strictly to observables and to nothing else would be sheer hypocrisy. The fact is that the difficulty of actual measurement has been confused with the supposed inherent impossibility of even conceptual perception. The claim to reality is based on the possibility of conceiving it and not on the possibility of actually making observations. Heisenberg's theory creates big gaps in the mental picture, which he makes no attempt to fill, and in fact cannot fill. He, therefore, asks us to shut our eyes against them and not think of them at all, but console ourselves by trying to believe that they do not exist. If such an attitude of mind were to be universally adopted, the inductive method of reasoning will be completely abandoned, contemplation of causes and effects would be forbidden, and experimental research may come to a standstill. The only consolation which Heisenberg can offer is "Mathematics has been adopted to do away altogether with any mental or physical picture. For visualization, we must content ourselves with but incomplete analogies, the wave picture and the corpuscular picture."

It is not quite accurate to say that no single experiment can be devised which would show both the corpuscular and the wave aspects at the same time. If we let two beams of electrons pass through two parallel slits and then fall on a scintillating screen, we shall find a series of diffraction bands, each of which will exhibit the scintillation phenomena as well. We thus observe for the swarm both the aspects simultaneously, *i.e.*, electron hits distributed in a series of bands. Similarly, the electron hits in each of these bands can be detected by photoelectric effect. It would be difficult to accept the explanation that the same waves pass through both the slits, even though far apart, interfere to produce the wave effect, and at the same time reunite to produce the corpuscular effect of scintillation and the photo-electric effect

Wave Mechanics

Schrodinger has frankly started with a wave equation as his fundamental postulate, without any attempt to give it any other artificiality or mystery. The first attempt made by *de Broglie* and *Schrodinger* to represent the electron by a wave packet (Wellenpacket) of finite dimensions did not succeed. Since then the latter has not pretended to offer any explanation of the reason why, nor attempted to give any physical significance to his mathematical wave. The straightforwardness

of his method has led to the tremendous advance which Wave Mechanics has made in quantitative deductions, and that would have been altogether impossible if Physics had remained entangled in the labyrinth of artificial matrices. But as physical significance is lacking, the advance qualitatively is almost nil. We have the idea that matter is, in some mysterious unknown, unthinkable way, always accompanied by mathematical waves which give good results without disclosing their true nature. A closer examination of his equation again brings out the fact that his theory also is based on the assumption of the existence of quanta. The wave-length and the frequency are not to have all possible values, but only certain definite values.

Obviously, the assumption of a wave, with crests and troughs, together with the boundary conditions that the amplitude vanished at the two ends, must mean that the number of half wave-lengths in between is an integer. If we have a wire fixed at its two ends, and transverse motion be given to it, it must of a necessity take the form of an integral number of half wave-lengths. The credit which goes to Schrodinger is his discovery of the appropriate wave equation.

But in essence he also has to fall back on the two postulates ; (1) wave equation, and (2) discreet units. The fundamental difficulty lies in the fact that waves have no meaning without a medium and the existence of a medium is denied. If electrons were to consist of Schrodinger's wave groups, they would not in general preserve the same dimensions, but would spread out in space with time, whereas the electrons do in fact retain their dimensions. Thus if there is any sense in thinking of waves, one cannot get over the incontrovertible fact that they cannot escape gradual diffusion, as they must continuously spread all over space. Yet we know that fossils have preserved their forms unchanged for several hundred million years ; and it cannot be denied that Cosmic rays take millions of years to come from even beyond the nebulae. If the universe consisted of waves only, it would have become diffused long ago, and would not exist in any material form. Further, even if once diffracted by a crystal, his wave-packets also would be completely dispersed and destroyed, and no corpuscles would be traceable in the scattered beams. The gross artificiality of the mathematical wave becomes exposed at once when the interaction of two particles is considered. His differential equation then involves six independent co-ordinates, as if there were a space of six dimensions. With n particles a space of $3n$ dimensions is required. We are however assured that the multi-dimensional wave-picture is a real one, and that our inability to visualize it is due entirely to our incapacity to grasp such a superspace. It is simply incredible that physicists should accept such a notion. It would be impossible to attribute to the square of the modulus of these numerous co-ordinates any physical meaning. Another serious inconsistency lies in the circumstance that while regarding the charge as being distributed over the whole

space; he still takes the potential energy as $\frac{e}{r}$, which can be true only if we regard the electron as being at a definite distance r from the nucleus.

It is refreshing however to find that Schrodinger makes no secret of the incompatibility of the two aspects. "The light ray, or track of the particle, corresponds to a longitudinal continuity of the propagating process (in the direction of the spreading); the wave-packet, on the other hand, to a transversal one, *i e*, perpendicular to the direction of the spreading. Both continuities are undoubtedly real - the one proved by photographing the particle tracks and the other by interference experiments. And yet we have not been able to bring the two together into a uniform scheme."

Probability Waves

The impossibility of understanding what these non-material, unreal, purely artificial and mathematical waves can be is an insuperable difficulty. Max Born has stepped in to suggest that they are waves of probability—with all respect, this makes confusion worse confounded. We have now abandoned even talking of the motion and trajectory of corpuscles, it is the fashion now to speak of the motion and trajectory of "element of probability." We glibly talk of the dualism of waves and corpuscles without intending to imply the sense they connote; we not only leave the exact relation subsisting between them in total obscurity, but repudiate even the reality of the two terms of the duality. Born has emphasized that the wave is in no sense a physical phenomenon but a mere symbolic analytical representation of certain probabilities. These waves of chance are incapable of being located in space and time; they are mere something unthinkable expressible only by mathematical equations. He has gone further and denied that there are any strict laws other than the laws of probability.

Let us pause and reflect on the absurdity of the present mental attitude. We talk of an atom as a unit and give it an individuality; we assert its magnitude, mass and charge, and in the same breath regard it as a diffraction halo arising from an electron wave intercepted by its own nucleus. We photograph the actual track of a particle. Is it satisfying to be told that the track is a but slender bundle of equally possible tracks between which the wave fronts form a lateral connexion? The modern Physicist would make us believe that a free electron is really an infinite monochromatic wave extending from infinity to infinity with an infinite number of crests and troughs throughout its infinite length. The probability of the electron being at any crest is the same all along the train, and so it may be anywhere from $-\infty$ to $+\infty$. If it suddenly collides with another particle it may have to travel from $\pm\infty$ with infinite velocity (much greater than that of light!) to arrive at the point of collision instantly.

We observe that two beams of concentrated quanta of energy after passing through two parallel slits reach a photographic plate and produce a series of parallel fringes. We are called upon to believe that these are waves of probability whose interference phenomena produce a series of regions of greater and less probability, and that carriers of energy are found only in regions of high probability. We find a particle in a certain region; the explanation offered is that we find it there because there is a probability of its being found there. It is a wonder how practical physicists do accept all this. Again, we bring about the collision of two particles in a Wilson Cloud Chamber, trace their tracks, and calculate their momenta and energies; what does the new Wave Mechanics say to that? It asks us to believe that there were two infinite trains of chance or probability extending from $-\infty$ to $+\infty$ and existing from eternity and destined to subsist for eternity, and by a sheer accident these two mathematical, artificial, and unreal trains of probability suddenly narrowed down to two points and hit each other like billiard balls! One wonders what the future generation of scientists will come to think about all these hypotheses. May it not be that they will find it incredible that powerful intellects of the twentieth century should have indulged in such ludicrous theories?

The ordinary concept of a wave of probability would be devoid of all sense, for if crests and troughs are to cancel one another, the probability troughs must be given a negative value; without their being of opposite sign the zero value will not be obtainable. A negative probability is simply absurd, as one can understand a probability being large or small, or even zero, but a negative probability can have no intelligible meaning. Hence the wave function in Schrodinger's equation cannot possibly be interpreted as the probability, and so the product of ψ and its conjugate ψ is arbitrarily taken to represent it. Thus for the probability, a complex argument is substituted without explaining its significance, and it is made out that it is the argument of the probability that is propagated in an undulatory form. The square of the modulus of the variable in Schrodinger's differential equation cannot represent the electric density widely distributed continuously in space, and so we are told that it is only the probability of finding the electron at the point. Even this is useless for calculating the effect of an external electro-magnetic field. As no meaning can be attached to spacio-temporal co-ordinates, the analogy of the probability equation has been seized upon as a possible escape from an *impasse*, knowing fully well that no physical significance can at all be given to it. The artificial substitution of an imaginary quantity transforms the wave equation into a symmetrical form which happens to be of the type satisfied by functions with real exponentials familiar in the theory of probability. One could not make the concept any more mystical! The so-called undulations are supposed to represent alternations in the probability of finding a particle somewhere. But can these alternations combine and interact to produce interference bands or diffraction rings? If we are to accept such artificial

mathematical devices not capable of any real physical significance, we would make ourselves slaves of mere mathematical symbols. The philosophic mind would repel against such a counsel of despair.

Dirac and others have tried to get over the difficulties by the method of second quantisation, which regards the wave functions as being themselves numbers; but the method is extremely artificial and unsatisfactory. Dirac in his radiation theory employs the language of the particle representation, but makes use of the conclusions drawn from the wave theory in his derivations. Wave Mechanics had represented the wave supposed to be associated with an electron by a single scalar function. satisfying the classical type of wave equation with partial derivatives of the second order. It could not therefore permit of any explanation of vectorial wave phenomena. Dirac has assumed that such a wave should be represented by a function of several components, four in number. He has linearised the Hamiltonian function and obtained four simultaneous partial differential equations of the first order which these ought to satisfy. These equations automatically introduce the properties of angular momentum and magnetic moment, without any clear physical perception. But Dirac's equations provide solutions involving negative energy to which would correspond electronic motion with paradoxical properties, for instance; by checking an electron with negative energy we should increase its velocity, which is not found to be true. Again, the possibility of an electron in motion being in a state of negative energy is self-contradictory. He has therefore been forced to assume that in the case of electrons all possible state of negative energy are normally occupied in the entire Universe, and to assume that this uniform density of electrons is quite incapable of being observed. To explain the observable electrons he further assumes that there are in the Universe more electrons than are required to occupy all the states of negative energy and that the surplus electrons occupy the states of positive energy which are experimentally discernible. Lastly, he has assumed that one of the electrons with negative energy can pass into a state of positive energy under an external influence and become disconnected as a hole or lacuna in the distribution of the electrons with negative energy—an anti-electron or positive electron. This disappears as the hole tends to fill up, but it is not stated how.

The scalar ψ could not be identified with an electro-magnetic wave represented by two vectors in the fields of Maxwell and Lorentz. Even the four components of Dirac's ψ-wave lack the character of the components of a vector, making it impossible to identify them with the electro-magnetic field. In spite of various fruitless attempts made in this direction, the two mathematical entities, the classical electro-magnetic wave and the imaginary ψ-wave, cannot be reduced to each other. There is no possibility of deriving the light fields of the classical theory from the associated wave of Wave Mechanics. Dirac has attempted a reconciliation between Quantum Mechanics and Relativity by his linear equations, which show invariance

of form for the Lorentz transformations. But the interpretation now-a-days given in terms of generalised probability assigns a specific role to Time; impairing the relativistic symmetry of the four space-time variable. This dissymmetry between Time and Space is due to the existence of a privileged sense for the time variable, and the persistence of physical units in time.

While spin and angular momentum are attributed to an electron, even the individuality with which we started is denied to it, and the electron is now considered to be "all over the orbit all the time." In the words of de Broglie, 'Dirac's Theory seems to suffer from an '*embarras de richesse*.' However, Dirac's theory of the magnetic electron (with the new mechanical and electro-magnetic properties of spin and magnetic moment is perhaps the most popular, but even that faces many objections which it is incapable of removing.

Even the new method of measurement of length and synchronization of clocks in a Galilean reference system is rigorously valid only for great masses in the microscopic sphere. In the Quantum Mechanics the method breaks down as the simultaneous measurement of length and time is unpracticable. Relativity has hardly any place in the atomic regions. Another new method of applying quaternions has been invented to conserve the four-dimensional character of physical quantities. The dynamical variables are not mere Heisenberg's matrices, but quaternion matrices. But this theory is still in an undeveloped stage.

Another futile attempt has been to invent a Quantum Theory of the Field by imagining two kinds of photon, the longitudinal photon corresponding to the electrostatic field and the transverse photon corresponding to the Maxwellian electromagnetic waves. But the results are disastrous. It cannot give to the electron any finite radius and must treat it as a geometrical point with infinite energy, and fails completely when dealing with re-actions between fields, charges and currents. Dirac's theory of the classical electrons, with retarded and advanced potentials, is the latest in this field, but that too has not yet been fully developed.

Statistics

When observing the behaviour of a large swarm *en masse*, individual action is obliterated and only the statistical effect is observed. In classical Statistics, particles were supposed to be distinguishable, but not so in Quantum Mechanics. Particles divide themselves into two classes as regards their statistical properties, and two kinds of statistics have accordingly been invented. The Bose-Einstein Statistics is based on the assumption that the number of elementary particles in the same state can be as large as we please. The phase space is divided up into cells, and then it is counted how many cells contain 1, 2, 3, etc., particles. It is assumed that they behave like perfect gas in which no atom has

any influence on another. This Statistics applies when we deal with symmetrical wave functions, and photons and nuclei of even mass numbers are governed by it. The Fermi-Dirac Statistics, on the other hand, is based on the assumption that the presence of one particle in a given state absolutely excludes the presence of another in the same state. In this way Pauli's Exclusion Principle is made its main foundation. This Statistics applies to anti-symmetrical wave functions, and governs particles like electrons and nuclei of odd mass numbers. No theoretical explanation has been given so far why the Exclusion Principle should apply to the charged (light) electrons and positrons and chargeless neutrons and neutrinos, and yet not apply to the charged heavy electrons, whether negative or positive, and the chargeless photons and neutrettos.

If we dispassionately survey the whole position, we cannot but admit that we are being whirled round in a vicious circle—we start with a corpuscular concept of localized energy, then we add to it an undulatory character, and ultimately we deny the reality of both. In the end, we are left with certain mathematical equations, devoid of all physical significance. When physical interpretation is attempted, it becomes ridiculous. The net result is that there are two rival theories in the field, neither of which is comprehensive. The Electro-Magnetic Theory fails to explain corpuscular phenomena like Scintillation, Photo-electric effect, Compton effect or Raman effect. The Wave Mechanic is incapable of explaining electro-magnetic phenomena like the constancy of the velocity of light in vacuo, the value of the ratio of the electro-static and electro-magnetic units; nor can it at all explain vectorial wave phenomena like polarization, double refraction, etc. Science badly needs a comprehensive rational theory, as without it we are being driven further and further away from reality.

Two Big Fallacies

A curious notion is prevalent that the classical theory explains large-scale phenomena, whereas the modern theory explains the atomic phenomena. Really, interference and diffraction are just as much a small scale phenomena as Compton effect or scintillation. The former are a manifestation of the interaction of light photons, while the latter of the interaction with material corpuscles, both on the microscopic scale, and none on the microscopic one. The true difference lies in the fact, grievously overlooked, that the former show the behaviour of swarms of corpuscles, while the latter that of individual corpuscles.

The wave effect is the effect of a large swarm, whether dense or rare. It may be justifiable to say that the swarm behaves like a wave, but it is absurd to go further that each entity of which the swarm consists itself behaves like a wave. No one in his senses would ever try to deduce the individual characteristics of soldiers from the movements of a large army of them. Soldiers marching in rows or files

would produce a wave picture from a distance, but who would say that each of them is himself a wave? The average result of the actions of a large number of persons forming a group is one thing, and their individual action is quite another. If the population of a country shows a steady increase, it would be ridiculous to infer that there are only births and no deaths in the land, or if it shows no change, to infer that no one is born or dies in the country. An equal absurdity underlies the assumption that because a swarm of photons, or material particles, appears to behave like waves they are individually waves. It is surprising that such an elementary consideration is overlooked, and it is not realised that in certain conditions a group of discreet units can produce a wave effect. To know the character of photons, electrons and protons we ought to watch their individual behaviour as manifested by their collisions; in such actions they undoubtedly manifest their corpuscular structure. Interference and diffraction are the statistical effects of swarms, and we should not seek to know their nature and structure from these phenomena. The partial success of the wave theory does not prove the wave-character of individual entities. The same serious fallacy attaches to the modern notion that there is a wave associated with each electron. A single electron never exhibits any wave properties, and so it is quite wrong to associate any wave with it. If a wave is to be associated at all, it should be with a beam of electrons. The whole modern idea of the wave aspect of one photon, or one electron is altogether misconceived, and is based on an utter failure to discriminate between the different actions of individuals and swarms.

The second big fallacy which has dominated Physics for well over a century is the wholly unjustifiable assumption that interference and diffraction cannot be explained on any corpuscular hypothesis. All the physicists take it to be a fundamental axiom, requiring no proof. It is true that Newton's corpuscles could not, but they are not the only form of discreet units Waves have no meaning without a medium; and as a medium has undoubtedly to be denied, we must inevitably fall back on corpuscles. The main characteristic of a wave is a succession of crests and troughs, which is an alternation of maxima and minima. Waves must be abolished with the medium, but the periodic alternation of maxima and minima can be retained. Any rotating system which is not perfectly uniform in all directions can produce a periodic recurrence of maximum and minimum effects, which can take the place of a wave.

The Problem and its Solution

If we consider the various properties of light, we can formulate the problem that confronts us:—

(1) It is something which manifests itself as a swarm of discreet units, which can collide with material particles.

(2) It subsists in its form of localized energy even at long distances from its source.

(3) In its interaction with matter it acts in irreducible quanta.

(4) It has longitudinal motion, and approximately rectilinear propagation.

(5) It has the following characteristics analogous to a wave motion :

(a) Its motion is periodic.

(b) Its oscillation is transverse, showing polarization.

(c) It has maximum and minimum effects which can with a phase difference produce interference and diffraction.

(6) It is an electro-magnetic phenomenon, so that its plane of polarization is rotated by a magnetic field as well as an electric field.

The obvious solution of the problem is that light is a binary corpuscle, consisting of one positive and one negative charge rotating periodically round each other, under their mutual force of attraction, the whole system moving forward with high velocity. This fully explains the dual aspect of light, reconciling all the known phenomena. This Rotational or Binary theory* can also account for an inherent loss of energy with time, doing away with the supposed recession of nebulae. Similarly, atoms and molecules show maximum and minimum effects, and so would an electron, if considered as a rotating magnet. All this restores reality to Nature.

*For its mathematical development See Pr. Nat. Ac. Sc., India, Vol. 6 (1936), pp. 348–366 and Vol. 7 (1937). pp. 65—84.

ADDRESS OF THE CHAIRMAN

SPEECH BY THE HON'BLE SIR MAURICE GWYER, K.C.B., K.C.S.I., D.C.L., CHIEF JUSTICE OF INDIA AND VICE-CHANCELLOR OF DELHI UNIVERSITY, AT THE ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES, INDIA, ON FEBRUARY 22. 1941.

MR. PRESIDENT AND MEMBERS OF THE NATIONAL ACADEMY OF SCIENCES,

Before I begin my address, I hope that I may be permitted to strike a personal note and to thank Sir Shah Sulaiman not only for the much too kind things which he has said about me today, but also for the honour he has conferred upon me by asking me to take part in today's ceremony. Sir Shah Sulaiman and I are colleagues in the Federal Court. In that capacity we are by the happy tradition of the Bench brethren to one another; and in our case I hope that the expression is not merely a conventional one. We have sat together now for nearly four years, but our acquaintance began some years before that when Sir Shah was one of the members of a very remarkable tribunal which sat in London to determine certain questions between the Government of India and the English War Office. I have marvelled at his extra-judicial studies and researches and at the courage with which he assails the giants of the scientific world. These matters are far beyond myself, but, as someone once said in similar circumstances, "we may admire where we cannot presently understand." I know the time and labour which he has given to this Academy during the period of his presidency. He lays down his office when the Academy seems to have passed the troubles of childhood and to be entering upon a period of vigorous growth; and I do not doubt that the additional leisure which he will now have at his disposal he will devote to the furtherance of those studies which have already attracted the attention of scientists throughout the world, even though he may not have succeeded as yet in convincing all of them.

It is indeed an honour to inaugurate a session such as this; and I deem it a special privilege to have the opportunity of doing so within the precincts of the University with which I am associated as Vice-Chancellor. It is a very real satisfaction to all those who live in the capital city of India that you should have selected Delhi as your place of meeting this year, a city with a great and famous past and destined, I believe, to have a still greater and more famous future. It is no less a satisfaction to the University of Delhi that you are meeting in this place; but I hope that I shall not be thought ungracious if I say that I could have wished that you were meeting here twelve months later, for you would in that event have found yourselves in surroundings very different from those which greet you today. We are at the beginning, as I hope, of a great revival in this University. We are re-organizing ourselves

and putting our house in order. We are building a new Science College, and we are attracting to this site one by one the constituent Colleges of the University. You must therefore forgive us if we cannot welcome you today in the building and in the surroundings which we could have wished that you should see; but we hope that the signs of activity and progress which may have attracted your attention will have served to convince you that what you have heard about the new ambitions of this University is not without foundation. A year hence the building in which we now are will have been restored and renovated. It will be once more at the service of study and learning ; and it will, I am firmly persuaded, be infinitely more attractive to the eye than it is at present. Our Science College will be at work. I cannot prophesy whether the whole of its new building will be complete, though I am not without hope that Providence may inspire one of the race of philanthropists, which happily still flourishes in this land, to enable us to complete it; but, as I have said, whether complete or not it will be at work. And you will have seen from that part of it which is already built and from the plans which my colleagues will be only too glad to show you, the form and amplitude of the finished structure. I take it as a most auspicious omen that your Academy should be visiting this infant of ours at so critical and interesting a period of its life; and I trust that you will not conclude your proceedings here without conferring your blessing on it in accordance with that gracious and graceful custom in this country which consecrates the first association of *chela* and *guru*.

The purposes of such an Academy as yours are manifold, but I take it that you regard some of them as of primary importance. It has been said that science has no frontiers, but I am not sure whether in the past it has been equally true that science in India has had no provinces; and perhaps the chief purpose of your institution is to demonstrate the essential unity of Indian science, so that those who have achieved fame among their fellow-workers by their researches and their additions to knowledge will be proud to have contributed not only to science in Bengal, or Madras or the United Provinces, or as the case may be, but to Indian science as a whole. Next, your Academy affords a meeting ground where scientists may come together at regular intervals and renew their contacts and friendships with other workers in similar fields, and by exchanging ideas with one another stimulate and enlarge their own activities. I do not forget the annual Science Congress which is held, I think, at Christmas time each year, and out of which indeed, I understand, this Academy itself sprang; but your body is a more permanent organization and the Journal of its Proceedings records in more permanent form and at more frequent intervals the contributions of your members to those branches of knowledge in which they labour. Lastly, your Academy will give a corporate sense to all its members as men striving in a common cause. I am not so innocent as to believe that scientists are always of one mind. Even lawyers

sometimes differ, and dissenting judgements are not unknown in the Federal Court. Bur if you do not always speak with one voice you will at least be able to speak with a united voice and that is a great thing. I recall two famous countrymen of my own, each a man of strong and decided views, of whom it was said in a memorable phrase that they lived all their lives in friendship and harmony, 'except in opinion not disagreeing;' and I hope that any differences of opinion among you may serve to increase rather than diminish the friendship and harmony of all your members.

I spoke a few moments ago of the satisfaction which all citizens af Delhi feel that you should be meeting here. I believe it is for the first time, but I hope with all my heart that it is not the last; and I venture also to hope that perhaps one day you will have more permanent interest in this capital city. The future history and constitution of India are matters falling within the sphere of a department of science which is not represented in your Academy, nor would it in any case be seemly for me to indulge in speculation upon them. But whether, as I gather from some newspapers, the present Indian Provinces are one day to be divided up into an infinite number of unilingual areas, or whether, as I gather from others they are to be grouped together into new territories and kingdoms, I cannot but think that Delhi itself will still remain the symbol of something which transcends local and communal divisions, a symbol of the unity which can emerge out of diversity. I am not now speaking, and indeed I may not speak, of political matters; but, politics apart, there is also an intellectual and cultural unity which can surely find its home here. The city of Delhi belongs to no one province, but to India itself; and I look forward to the time when the city may become once more the centre of a generous and comprehensive culture, in which institutions such as yours will find their natural and spiritual home. I hope that in this intellectual movement the University which I represent will one day play a noble part; for I have an ardent belief in its future, even if I shall not myself live to see the fruit of our labours. And that is why it is not only a satisfaction to us but also an immense encouragement that your Academy is here today.

I was not myself privileged to receive a scientific education. My education both at school and at the University was of a severely classical kind; but I am convinced that such an education, especially if combined, as it was in my own case with the study of the law, is able to produce results which are today sometimes claimed to be the exclusive monopoly of an education in science. I think that the severe mental discipline which it provided strengthened and invigorated the mind, taught us habits of accuracy and concentration, inspired us with an ardent love of truth, enabled us to grasp the general principle implicit in a series of facts or phenomena, and instructed us in the processes of reasoning and logic. Indeed, if I may respectfully say so in a gathering like this, it did more; for it did not neglect the emotional side of human life and it

opened our eyes to the beauties of art and literature. But where I think it failed was in withholding from us all knowledge of those far-reaching and fundamental conceptions with which modern science has illuminated the furthest recesses of the physical universe. There is a grandeur about these conceptions which cannot but make an instant and vivid appeal to any young man of sensibility and imagination.

We have all of us read, and perhaps have known from personal experience, of events which have suddenly and unexpectedly had a profound influence upon the lives of individual men, such as the reading for the first time of a particular book, a meeting with some eminent person, personal contact with some historic episode; and we have seen their psychological effect,—how the mind can be, as it were, suddenly flooded with light and everything made to stand out in high relief, so that in that single moment of time the whole of a man's career is perhaps pre-determined, perhaps the seed sown of a new philosophy, perhaps even a sinner turned into a saint. Not dissimilar seems to me the effect upon a young and impressionable mind of the wonders and discoveries of physical science. They inspire and they exalt; and every man who becomes familiar with them by a study of the principles on which they are based and the infinite potentialities which they enshrine finds his intellectual powers stimulated and augmented in an extraordinary degree. It is a matter of infinite regret to me that my own knowledge of these things is hearsay only; and it is for that reason that I should like to see every young man made acquainted as part of his general education with the elements of scientific knowledge and method. But you, gentlemen, on your side will not, I hope, forget the claim of the humanities when you are training up your own young scientists. I do not think that any scientist is the worse for a knowledge and appreciation of art and literature. There are, as we all know, pedants in either camp; and the best cure for pedantry is the touch of scientific imagination in the one case and of humaner letters in the other. Why then should we regard these two spheres as in opposition to one another or as mutually exclusive? Each has something to teach and each has something to learn; and it should be the glory of the true University not only to welcome both but to ensure that they live together in harmony. But I would not have you think that I forget the great contributions which science itself has so often made to literature. How much poorer would the English language be without Sir Thomas Browne's opulent and glowing prose, or the rich and forceful terseness of style which Lord Bacon made his own, or the marshalled eloquence of Charles Darwin's epoch-making book! And I have known works by modern physicists, in which *lucidus ordo*, that quality in writing to which the Roman critic assigned so high a place, the clear and orderly sequence of thought and argument, has been such that a layman like myself can read them with delight and almost deceive himself into believing that matter so perspicuously presented must necessarily be easy to follow and even to comprehend.

We are meeting today under the shadow of a great war, and it is a bitter reflection on our civilization that it is to the urgent necessities of warfare that so many remarkable discoveries and inventions owe their origin, which might have continued for many years unknown in time of peace. Yet out of evil good may come, and war-time inventions may at a later date be made to serve the interests of nations once more at peace. I have heard scientists blamed for the use which warring peoples have made of their skill; but this is an unjust charge. There are few things, however beneficial in themselves, which cannot be prostituted to the baser instincts of mankind; and if leaders of great States are willing to say "Evil, be thou my good," it is they who must take responsibility for the misuse of the power which science has given to men over the forces of nature. One day, and it is the prayer of all of us that that day will come soon, the war will be over; and it is then that Science will resume the responsibilities which are more rightly hers. She has it in her hands to add infinitely to the comfort and to the happiness of mankind. The tireless and unselfish labours of her votaries are at the service of the world, if the world chooses to use them; and it is for the peoples of the world, when they have re-asserted the rights of which dictators would deprive them, to see that the fruit of those labours is made available to all—to the poor no less than to the rich. But this desirable end can only be secured if people are willing to choose wise leaders who have some understanding of the scope and potentialities of modern science, who are willing to seek advice and guidance on these matters from those who are able to give it, and who remember that the blessings which it is within the power of science to bestow belong to the whole world and not to this nation or to that.

There was once thought to be an irreconcilable conflict between the ideas and conceptions proclaimed by modern science on the one hand and the theologians and others who supported the old traditionalist systems on the other. In my own country the conflict for a time was bitter and acute, but it is now at an end; for each side has realized that any system of thought which claims to embody principles of truth is worth nothing at all if it is not prepared to submit itself to criticism and examination. If the truth is there, criticism and examination will only make it more manifest; if it is not there, it is better that the system itself should no longer cumber the earth. Nothing therefore which claims to represent any aspect of the truth can at the same time claim to be exempt from criticism or discussion, subject only to one qualification, but it is an important qualification, and it is this. In the last century there came before the English Courts the question of the right to criticize or attack certain beliefs held by many people; and the Judge who tried the case held that even fundamental beliefs might be criticized, provided that the decencies of controversy were observed. Men hold with tenacity and regard with veneration the beliefs and traditions in which they have been brought up; and if these traditions and beliefs should become the subject of criticism, it is wrong that

things should be said or done which outrage, or are even wounding or hurtful to those to whom such beliefs and traditions are dear, however mistaken they may seem to be. I do not believe that any scientist worthy of the name would refuse to subscribe to that proposition. We have all known men who, intoxicated by some novel idea, lose no opportunity of preaching it in season and out of season, at inappropriate as well as appropriate times. Generally they are young men who learn better as they grow older; but they can be the source of infinite mischief until wisdom comes to them. The cause of truth is not advanced by conduct which creates in your adversary a state of mind which makes him refuse even to listen to what you have to say.

I have ventured to say this, because this country is above all others a land of customs and traditions; customs and traditions which have been handed down from generation to generation, perhaps for thousands of years, and which may have behind them the strongest social and religious sanctions which it is possible to concieve. In the course of centuries their true origin and meaning has sometimes been forgotten and has sometimes been overlaid by accretions or obscured by misunderstanding, so that it is not always easy to disentangle the true from the false. I can think of few countries in which modern science has so vast a field in which to play its beneficent part. I picture it to myself as a strong and mighty wind, purifying and invigorating, which will blow through the country, searching out all the dark nooks and crannies and sweeping away all the dusty accretions of ignorance and superstition, leaving behind only the pure residue of gold, but dealing gently nevertheless with things, however erroneous, which the passage of years or the habits of many generations have made venerable. Your Academy can, and I hope will, lead and inspire such a crusade as this, for men of science are realists, who look forwards rather than back.

I should like to add a few words on the subject of scientific research. Your body, which represents, I understand, the great majority of scientists in India, is in a position to exercise a powerful influence in the matter of the promotion and co-ordination of research. I am well aware of the value of the research work which is being done in different parts of India. In some cases I have had an opportunity of seeing it with my own eyes, in others I have learned of it from friends and correspondents. There is the work which is being done at the different Universities, among whom I hope that within the next twelve months Delhi University will be for the first time included. There is valuable work also being done in Colleges throughout India. There are Government or quasi-Government institutions like the Imperial Agricultural Research Institute, New Delhi, the Forestry Institute at Dehra Dun, the Indian Institute of Science at Bangalore and the School of Tropical Medicine and Institute of Hygiene at Calcutta, to mention only a few. There are also Institutions which owe their origin to the generosity of individuals, which

are mainly devoted to industrial research; and to these will, I hope, there will soon be added one not far from this very place, which a great industrialist of Delhi has promised to build and endow, but which is to be managed by a Governing Body on which public representatives will be in a majority. I do not profess to have studied all the ramifications of this subject, but I have asked myself whether the time has not come for some greater measure of co-ordination among these various bodies and institutions, both to prevent duplication of work and to direct the efforts of researchers into the most fruitful channels. I always hesitate to compare the arrangements of one country with those of another, and especially where the comparison is between my own country and India, because the circumstances and conditions of the two are so dissimilar. I might mention however that there are in England two very important bodies, known as the Committee of Scientific and Industrial Research (though I believe it has now acquired the status of a Department) and the Medical Research Council respectively, which organize and develop research in these two spheres. They are financed by means of generous Government grants, which are perhaps too much to hope for in India at the present moment, and by private benefactions; and they are directed by men whose eminence in their own sphere is recognized and admitted by all. I had something to do myself with the Medical Research Council in its early days and I knew well its first Secretary, the late Sir Walter Fletcher, whose early death was a grievous loss to English science. The method adopted by the Council was to undertake research by means of teams of workers by no means confined to the staff of scientific men in the permanent service of the Council, but including also part-time or voluntary workers in Universities and other scientific institutions throughout the kingdom who were willing to offer their services. I have no personal experience of the work of the Committee of Scientific and Industrial Research, but I have no doubt that it follows similar lines. I do not think that in India there is as yet any similar body, except perhaps the Imperial Council of Agricultural Research and the new Industrial Research Board, which has been recently established to deal with war problems, but which will perhaps assume a more permanent form later on. It seems to me that other institutions dealing with no less important aspects of scientific research are also wanted, together with some body perhaps to co-ordinate their efforts generally, and to act as a clearing house of new ideas. It might begin in a more limited form with an attempt to co-ordinate the research work of the Universities, and by some attempt to parcel out on a voluntary basis the different spheres of research for which the Universities might make themselves severally responsible. I think that some such body might play a very useful and valuable part in the future, and, if I may be allowed to say so, your Academy is perhaps in a better position than any body of men to make practical and fruitful suggestions to that end.

Gentlemen, let me say one word more in conclusion. You have, as I understand, modelled yourselves upon a famous scientific body in my own country, membership of which is one of the greatest honours open to a scientist. It has been well said that the doors of that institution will open to no influence, no matter how powerful or by whomsoever exercised, and that those only can enter who are able to pass that most searching of all tests, the approval of their work by their fellow-workers in the same field. Your Academy has also, I do not doubt, adopted the same golden rule and is firmly determined to adhere to it; and it would indeed be a sad day for science in the United Kingdom or in India if either the Royal Society or its younger sister here relaxed its standards in the slightest degree or permitted the intrusion of personal considerations in the selection of its members. By thus upholding a lofty and rigid standard of merit, you may exercise a profound influence upon educational standards and values throughout the whole of India. It is so easy to relax standards, and often so difficult to maintain that inflexible integrity which justice and truth exact. Your example will be watched and followed, and you will, as time goes on, become, I hope, the guardians of a great tradition.

You have honoured yourselves as well as science itself, if I may respectfully say so, by the election of your new President; and I rejoice to know that in this hospitable land men of great distinction and eminence whose presence would do honour to any country but who by reason of a vile and cruel persecution are exiles from their own native land, can find a refuge and an opportunity of employing in the furtherance of science the great gifts which God has given them. I think that nothing has been more shocking in all the horrors which have afflicted Europe than the fact that few or none even in their own professions have been found to protest against the cruelties and injustices perpetrated against helpless men. Your Academy, like the University of Allahabad and, I am glad to remember, many institutions in my own country and in America, have set an example which the dictators of Europe would do well to mark. You have demonstrated the unity of science; you have done homage to learning in the person of your new President, though he comes from many thousands of miles away; and you have shown by your action that you reject the theory that learning is the monopoly of any one country or race, but rather that it is held in trust by all countries and all races for the benefit of mankind.

Gentlemen, let me conclude this address by welcoming you once more most warmly to the city and to the University of Delhi and by wishing you a most profitable and pleasant stay while you are among us.

VOTE OF THANKS

In proposing the vote of thanks to The Hon'ble Sir Maurice Gwyer, K. C. B., K. C. S I., D. C. L., Chief Justice of India and Vice-Chancellor of the Delhi University, Professor A. C. Banerji, M. A., M. Sc., F. R. A. S., F. N. I., F. N. A. Sc., I. E. S., Fellow of the National Academy of Sciences, India, spoke as follows :—

On your behalf and on behalf of the members of National Academy of Sciences, India, I have great pleasure in expressing warmest thanks to the Hon'ble Sir Maurice Gwyer for inaugurating the Tenth Annual Session of the National Academy of Sciences, India. Before he came to India Sir Maurice was a distinguished Professor of the Oxford University. He is an eminent jurist and an acknowledged authority of constitutional law. He is a versatile scholar and has had ample administrative experience. His interest in matters academic and scientific is well known. We are fortunate to have him as the Chief Justice of the highest court in India—the Federal Court. He has taken upon himself the noble task of reorganising various departments especially scientific departments of the University of Delhi and making this University a model institution of its kind. Sir Maurice has, in his address, referred to the old Indian tradition of *Chela* asking for the blessings of his *Guru* and has requested the scientists who have assembled here to bless the Delhi University. I may here refer to another Indian tradition of *Guru* wishing that his *Chela* may become greater than him (*Guru*). We wish and pray that before long the University of Delhi will become a foremost centre of learning where students from all parts of India will flock to get the highest type of education and to undertake research work. Sir Maurice has also mentioned that differences among scientists would ultimately lead to harmony. I fully agree with him. Absolute uniformity in any order of things would lead to negation of progress. Differences amongst scientists resemble differences in musical tunes throughout which pervades an inherent harmony. Sir Maurice has truly said that whether there is truth, criticism makes it more manifest. Indeed true criticism instead of creating or accentuating disagreement would lead to ultimate unity of science. Sir Maurice has placed all of us under deep debt of gratitude by coming here and inaugurating the present session in spite of his multifarious duties and physical discomfort. I am sure my vote of thanks will receive your warm approval and unanimous acceptance.

VOTE OF THANKS

In proposing the vote of thanks to the Delhi University, Dr. Shri Ranjan, M.Sc. (Cantab.), D.Sc. (State-France), F.A.Sc., F.N.A.Sc., one of the General Secretaries of the National Academy of Sciences, India, spoke as follows :

On behalf of the Fellows and Members of the National Academy of Sciences, India, it is my pleasant duty to offer our thanks to the authorities of the Delhi University for giving us the opportunity to hold our Tenth Annual Session in this beautiful hall. They have made fine arrangements for the delegates who have assembled here from all parts of India, and have given us all the facilities for holding our Sectional Meetings.

APPENDIX 1

PROGRAMME OF THE TENTH ANNUAL SESSION OF THE NATIONAL ACADEMY OF SCIENCES, INDIA

Saturday, February 22, 1941

10-55 A.M.—Reception of the Hon'ble Sir Maurice Gwyer, K.C.B., K.C.S.I., D.C.L., Chief Justice of India and Vice-Chancellor of the Delhi University, in the University Hall, Delhi.

11 A.M.—Annual Meeting in the Old Viceregal Lodge.

(1) Messages of good wishes from the Universities.
(2) Secretaries' Report.
(3) Welcome Address by the Chairman of the Reception Committee.
(4) Address by the President of the Academy.
(5) Speech by the Hon'ble Sir Maurice Gwyer, K.C.B., K.C.S.I., D.C.L.
(6) Presentation of the Education Minister's Gold Medal.
(7) Announcement of the Office-Bearers for 1941.
(8) Vote of thanks to the Hon'ble Sir Maurice Gwyer, K.C.B., K.C.S.I., D.C.L.
(9) Vote of thanks to the University of Delhi.
(10) Photograph of the members and delegates.

2-15 P.M.—Meeting of Section I (Chemistry, Physics and Mathematics) under the presidentship of Sir Shanti Swarup Bhatnagar, Kt, O.B.E., D.Sc., F.N.I., Director of the Board of Scientific and Industrial Research, in the University Hall.

(*a*) Presidential Address.

3-15 P.M.—Meeting of Section II (Zoology, Botany, Geology and Agriculture) under the presidentship of Rao Bahadur B. Vishwanath, F.I.C., F.N.I., Director, Imperial Agricultural Research Institute, in the University Hall.

(*a*) Presidential Address.

4-30 P.M.—Visit to the All-India Radio Station.

5 P.M.—Tea by the Staff of the All-India Radio Station.

5-15 P.M.—Popular lecture on "Cosmography" (illustrated by lantern slides) by Prof. A. C. Banerji, M.A., M.Sc., F.R.A.S., F.N.I., F.N.A.Sc., I.E.S., Professor of Mathematics, Allahabad University, Allahabad, in the University Hall.

Sunday, February 23, 1941

2 P.M.—Excursion to the Delhi Cloth Mill and the Imperial Agricultural Research Institute.

4-30 P.M.—"At Home" by the Director and the Staff of the Imperial Agricultural Research Institute, New Delhi.

5-30 P.M.—Popular lecture by Prof. M. N. Saha, D.Sc., F.R.S., Palit Professor of Physics, University of Calcutta.

8 P.M.—Dinner (Indian style) by Sir Shri Ram and Lala Shankar Lall at "Shankar Niwas," 20, Curzon Road, New Delhi.

Monday, February 24, 1941

10-30 A.M.—(1) Meeting of Section I, in the Physics Lecture Theatre of the University.

(*a*) Reading of and discussion on original papers

(2) Meeting of Section II, in the Chemistry Lecture Theatre of the University.

(*a*) Reading of and discussion on original papers.

4-15 P.M.—"At Home" by the Reception Committee in the University Gardens to meet the Hon'ble Sir Maurice Gwyer, K.C.B., K.C.S.I., D.C.L., and the President the Hon'ble Sir Shah Sulaiman, D.Sc., LL.D., F.N.I., and the Delegates of the Academy.

APPENDIX 2

RECEPTION COMMITTEE

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THE HON'BLE SIR SHAH MOHAMMAD SULAIMAN, KT., LL D., D.SC., F.N.I., F.N A SC.

Chairman

LALA SHANKER LAL

Vice-Chairmen

Sir Shri Ram.
Seth Beni Pershad.
Lala Banwari Lal.
Lala Ram Roop.
Seth Lakshmi Narayan Gadodia.
Lala Suraj Bhan.
Lala Jai Narain Prasad.
Rai Sahib Lala Adishwar Lal.
Sardar B. S. Ranjit Singh.
Kripa Narain, Esq.
Rai Bahadur Ram Kishore.
Rai Bahadur Harish Chandra.
Lala Narain Dutt.
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APPENDIX 3

COSMOGRAPHY

By Professor A C. Banerji, M.A., F.R.A.S., F.N.I.. I.E S
Mathematics Department, University of Allahabad

From antiquity poets and astronomers have both been charmed by the depths and splendours of the Universe. Each expedition into remote space by means of instrumental methods has led to new discoveries. An astronomer now feels somewhat like Saul in Bible. The astronomer goes to collect pebbles but finds a kingdom rich in variety and grandeur.

January 7, 1610 was a memorable day for mankind. On that day Galileo discovered four of the nine satellites of Jupiter by means of the telescope which he had made. He was also able to demonstrate that Jupiter is the centre of a miniature sub-planetary system resembling the planetary system with sun at the centre.

The largest telescope is at present located at Mount Wilson in California Its reflecting mirror has a diameter of 100 inches and admits 250,000 times as much light as the unaided eye. A 200-inch telescope has just been erected at Mount Panovar in California which would give a million times as much light as the unaided eye.

In order to make a cosmographical survey of the Heavens I would request the audience to take a trip in the depths of space with maximum speed we can possibly have, *i e.*, with the velocity of light which is 1,86,285 miles per second. A navigation of the Heavens is full of interest and very fascinating. In a second and a half we shall reach our nearest neighbour the Moon. There is no life, no vegetation, and no atmosphere in the Moon. We shall only see deserts, plains, craters, mountain chains, and peaks.

In eight minutes we shall reach the Sun after travelling through ninety-two million miles. The Sun has a surface temperature af 5000°C and at the centre it may have a temperature of about 14 million degrees centigrade. You will have to be transformed into a " silicaceous animal" in order that you may not be burnt into ashes on the surface of the Sun. On its surface solar promenences or huge fountains of flames sprout out like " Jack the giant killer's bean stalk " with speeds of thousands of miles a minute. Faculæ are bright patches on its surface which are probably clouds of vapours. Sun-spots are relatively dark spots on the surface and are short-lived Their changes of positions readily demonstrate that the Sun is rotating from east to west. In our journey we come across Venus and Mercury. It is practically certain that there are no intra-Mercurial bodies brighter than the 8th magnitude, *i e.*,

having diameters larger than 30 miles in length. Venus is seen to have a very dense atmosphere. Now infrared light has a greater penetrating power than ultra-violet light. Even infra-red photographs fail to find a solid surface.

Now let us proceed on our journey away from the Sun. We come across Mars which is seen to have a distinct atmosphere extending to a considerable height as it is found that the ultra-violet photograph is distinctly larger than infra-red one. On the surface of Mars, many markings are seen. Schiaparelli and Lowell thought that they were straight markings or canals which had been artificially constructed and had oases connected with them. On the other hand, Barnard and Antoniodi think that these markings are nothing but separate dark patches which appear connected by straight lines to the eye which is struggling to study outlines in faint light. Certain seasonal changes are seen without doubt on the Martian surface. It is also found that polar snow caps shrink considerably in Martian summer and become much bigger in winter. Recent spectral observations reveal only traces of free oxygen in Martian atmosphere, this amount is insufficient to support animal life, but may perhaps be sufficient for growth of vegetation. If the markings or so-called canals are really straight and connected, and were artificially constructed, then it is quite possible that Mars at one time supported animal life and was the abode of intelligent beings which have now disappeared due to the escape of the most of the oxygen from the atmosphere.

Jupiter is the largest planet of the solar system and has got an atmosphere. We have recently calculated that the depth of the atmosphere is about 1300 kms. Belts on its surface are temporary markings showing that they are atmospheric in nature and have vigorous circulation. It has got nine satellites

Saturn with its ring system forms perhaps the finest object in the sky. The rings are supposed to be fragments of a former shattered satellite of Saturn. The outermost ring of Saturn has got a radius equal to 2·30 times the radius of the planet. If a small body rotates about a large body of approximately the same density, and if the radius of the orbit of the former becomes less than 2·45 times the radius of the big body, the small body would be shattered into tiny bits. After a very long lapse of time our moon would also be drawn down to within about 10,000 miles of our Earth and the former will be shattered into fragments. With the velocity of light we shall reach Pluto which is the outermost planet of our solar system in less than 6 hours Pluto may rightly be called the gate-keeper of our solar system. In our journey through the solar system we also come across diffuse bodies of very small mass which are called comets. The portions of each comet are kept together by gravitational pull. Within the solar system we have got 9 large planets, 26 satellites, more than 1500 asteroids, and about 1000 comets.

As we leave the solar system we meet nothing but dust and cosmic radiation for four years and a quarter till we reach the nearest star. Our solar system may be

compared to a city with its suburbs Outside the suburbs we get wide tracts of uninhabited region till we come to the nearest town. The distance of the nearest star " Proxima Centauri " is about 25 billion miles from the Sun. To measure such great distances it is necessary to use a convenient unit of distance. One convenient unit of the distance is the light year, *i.e.*, the distance traversed by light in one year moving with a velocity of 186,285 miles per second. The light year is about 6 billion miles. A wireless signal travels with the speed of light. Its speed is about a million times that of sound. Even the nearest star is at such a great distance that the inhabitants of Proxima Centauri, if there be any, would hear a terrestrial concert four years and a quarter after it has been broadcasted from the Earth. In about eight years' time we reach the twin stars Sirius. The larger of the pair Sirius is apparently the brightest star on the Heavens. Its more wonderful companion Sirius B is a dwarf star. Its diameter is 3 times that of the earth and its weight three quarters that of the Sun It consists of a very dense matter, the average density being 60,000 times that of water. One cubic inch of material in Sirius B or the amount which can be put into an ordinary match box will contain about a ton of matter. In about 135 years we reach a rich field of luminaries called the Hyades. In 323 years we reach a similar group of luminaries called the Pleiades which present a very beautiful spectacle in the sky. Its length is 10 light years from end to end. Clusters like the Pleiades and Hyades are called the galactic clusters which can be compared to our districts and divisions.

Within our own galaxy or Milky Way we come across three main types of nebula, *viz.*,

(1) Planetary nebulæ
(2) Diffuse nebulæ
(3) Dark nebulæ

Planetary nebulæ have no planetary system within them, but they appear to have finite discs when seen through a telescope. Diffuse nebulæ are irregular in shape, and their general appearance is like that of "huge glowing wisps of gas stretching from star to star." Diffuse nebulæ may also be compared to provinces and some of them have a diameter of 100 light years. The dark nebulæ do not shine and they obscure the stars which lie behind them.

In our journey through space we come across variable stars whose luminosities vary regularly and in some cases irregularly. There is one important class of variable stars called Cepheid variables whose brightness fluctuates periodically. In determining the distances of very remote stars and nebulæ, main reliance is placed on Cepheid variables. It has been found that Cepheids which have the same period are nearly alike in their properties, *viz.*, intrinsic luminosity, radius, spectral type, etc. The observed relation between the period and brightness is governed by what is called the period luminosity law. Miss Leavitt discovered in 1912 that the

intrinsic luminosity of Cepheid variables varies more or less directly as its period. For example, a Cepheid having a period of 40 hours has got a luminosity of 1600 times that of the Sun. Thus the intrinsic brightness of a Cepheid is found out. When the absolute and apparent magnitude of a Cepheid is known, a simple application of the inverse square law gives it distance. If two Cepheids A and B have the same intrinsic brightness and A appeared four times as bright as B, then B must be at a distance which is twice the distance of A. So the relative distances of Cepheids are known. Now the absolute distances of the nearest Cepheids are known by the parallatic method and hence the absolute distances of remote Cepheids are determined. Many clusters and nebulæ abound in Cepheid variables, and so their distances are determined.

All these galactic clusters and galactic nebulæ are comprised within a much bigger stellar organisation which is known as the Galactic system.

The form of our Galactic system is like that of a bun or a double-convex lens. Our Galactic system is a super-galaxy and we can compare it to a country. The diameter of our Galactic system is estimated to be one hundred thousand light years, and its thickness has been found to be about 15,000 light years. We can regard our Galaxy as an "Island Universe" in the vast depths of space. Our local Galaxy is the biggest of all the Super-galaxies. It contains four hundred thousand million stars, and its weight is equal to that of 2 hundred thousand million Suns.

Soon after we leave the Milky Way we reach two star clouds—Lesser Magellanic and Greater Magellanic clouds. Their distances are 85,000 light years and 95,000 light years respectively from us. They were discovered by the famous Spanish explorer, Ferdinand Magellan, who observed them in the Southern Hemisphere near the celestral pole in his first circumnavigation of the world.

In the Lesser Magellanic clouds we come across the star S. Doradus of absolute magnitude—8·9, having, amongst all the stars, maximum intrinsic luminosity which is about 270,000 times that of the Sun

As we cruise through the depths of space we come across many extra galactic systems or nebulæ Most of them have spiral forms. In about 680,000 years we shall reach the great Andromeda Nebula. It is a super-galaxy like our Milky Way, and has a diameter of about 86,000 light years. The mass of Andromeda Nebula is equal to that of thirty thousand million Suns. If the size of some of these nebulæ be reduced to that of the Earth, then on that scale our Earth would be reduced to a microscopic object which would hardly be visible even under a most powerful microscope.

The spiral nebulæ are rotating masses of gas. Our Galactic system is rotating like a gigantic cart-wheel and makes one complete revolution in about 220 million years. On account of this motion, the Sun and the stars in its neighbourhood reach velocity of 200 miles per second. The hub of the cart-wheel lies in the direction of a

massive star cloud where the constellations of Scorpio, Ophiuchus and Sagittarius meet. It is also believed that our Galactic system is also a spiral nebula in which a spiral arm passes from Carina through the Sun towards Cygnus.

Several super-galaxies possibly form a still larger organisation which is called Metagalaxy. A super-galaxy like our Galactic system can be compared to a country and a Metagalaxy to a continent. It is "all comprehensive but still incomprehensible." We have to travel for many hundred of million of light years before we can leave our Metagalaxy and reach the remotest depths of space.

APPENDIX 4

Section A.—Mathematics, Physics and Chemistry

PRESIDENTIAL ADDRESS

THE PRESENT POSITION OF SCIENTIFIC RESEARCH IN INDIAN UNIVERSITIES AND INDUSTRIES

By Professor Sir Shanti Swarup Bhatnagar, Kt., O.B.E., D.Sc., F.Inst.P., F.I.C.
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I am deeply conscious of the honour which the National Academy of Sciences has chosen to confer upon me by asking me to preside over the debilerations of the physical sciences section in their annual meeting to be held this year under the auspices of the Delhi University. I am neither a stranger to Delhi nor to the Delhi University. Since the very inception of this University, I have been connected with the various committees which were set up to report on the progress and further developments of its science laboratories and last year I served as Chairman of the Inspection Committee appointed to report on the progress of its constituent colleges. Perhaps it will not be out of place to mention here that just before my appointment to my present post, negotiations were in progress to have me in Delhi in connection with a private enterprise and they had reached such a stage that I had hoped that if they matured a little further, I might have had the full realisation of my fond dream of working in the closest co-operation with this University. Most of my intimate friends know how very much I should have liked and still like to work under the inspiring leadership of the Hon'ble Sir Maurice Gwyer who is now guiding the destinies of this University. Those who know me and the facts of the episode fully appreciate that it was not any love of money which led me to postpone the acceptance of the offer made to me. On the whole even financially it was more attractive than my present post and in any case it promised to afford to me comfort, and stability of home-life which as you all know my present post have completely denied to me. It was the command of His Excellency the Governor of the Punjab, based on a request from His Excellency the Vicerory and Governor-General for India and the Hon'ble the Commerce Member that made me accept the present post during the period of the War. Those of you who know the inner working of the mind of a student of science can well picture that my decision was also largely the outcome of my desire to be able to actively help my country and work in a laboratory which

the other scheme was to provide for in the course of time, but which did not and does not exist so far owing to the war conditions. If and when the call from Delhi comes again after the war I hope I shall not be found wanting.

I have chosen as the subject of my address to this learned body a topic in which most scientific workers are deeply interested, namely, the position of scientific research in our Universities and in our Industries.

Howsoever altruistic may be our outlook on life as students of science, we cannot be completely divorced from the world of stern realities. All those connected with University life whether as teachers or administrators are well aware of the appalling conditions, with respect to the employment of particularly the educated middle classes. I can speak of myself with certainty that as a teacher of over twenty years' standing, I have felt a cold shudder passing through me when I have been apprised of the hardship of the present-day student life and on occasions my faith in the prevalent system of University education has been rudely shaken. I know I am not the only one who feels that way. Talking things over with most of you, I have come to the conclusion that every teacher of science is thinking furiously to evolve ways and means by which he may help in alleviating this suffering from which even our most brilliant students are not immune. It is a well-known fact that the civil services still take away the best brains available to the country and the advancement of science, culture, industry and agriculture has to rest content with the efforts of the next best. This process must be reversed if we are going to develop rationally.

Research and scientific learning offer hardly any scope in this industrially backward country and the scientific workers in India are now fully alive to the importance of this aspect of our development. In this respect our Universities have a great duty to perform. So far the attention of the University authorities has been confined to providing laboratories and library facilities and although even in this respect some of the Universities have been criminally negligent, it must be said to their credit that they have done something to create the necessary atmosphere for scientific work. This task will remain unfinished unless they make suitable arrangements for the continuance of scientific work by providing for the employment of suitable teachers and research students without whom the building and equipment will be like the body without the soul. It is not infrequent in this country that after putting up fine laboratories and buildings, the Universities have to economise in order to keep things going and these economies are affected by cutting down the salaries of professors and teachers and altogether abolition or suspension of studentships and research scholarships. There is no wonder that posterity will pronounce on these temples of learning, a judgment which will be just but nevertheless heartrending and severe. The conditions with respect to the research-studentships are particularly deplorable. Is it not surprising that some of our Universities are allowed

to send up students for the highest degree without their providing for research facilities for their teachers or research-scholarships for their students? Even when research-scholarships are given, the provision is so limited and the scope so meagre that the net achievements cannot be of any consequence to the development of science or industry. I take this opportunity of drawing the attention of Vice-Chancellors and other administrators of our Universities to the urgent necessity of their keener interest in this most important matter. Most of them are experienced men well-versed in learning and letters and it does not seem proper for a man of my stature and age to offer advice but it nevertheless is a fact that in some Universities research is still considered a luxury to be postponed for consideration after all the necessities have been provided for.

This attitude can only have a limited justification. There is much in favour of the view that all Universities in India need not specialise in every subject of study, but whatever they select for specialisation in the Universities, should be up to the highest standard and facilities for research and extending the bounds of knowledge in these branches should be both adequate and satisfactory.

Nothing helps research and consequently industry more than a satisfactory provision of scholarships which will attract the best youngmen to the libraries and the laboratories It is only by offering suitable assistance to deserving candidates that the teachers of science can keep the talent from drifting itself away into more lucrative channels of civil services. This will also help the teachers in evincing more interest in extending the bounds of knowledge particularly with a view to train youngmen not only as cultured gentlemen but as individuals capable of earning their livelihood. Much as I value the benefits of academic learning which rises superior to considerations of a more utilitarian character, much as I should like some of our educated youngmen to live lives dedicated to the service of culture, to enrich their own minds and the minds of their countrymen with the treasures of philosophy and thought inherited from ages, I feel that the teachers should realize that generally speaking the interests of our country will be better served if we lay greater emphasis on, and make better provision for, practical, scientific and vocational education which will enable youngmen to stand the stress of modern competitive life. That this practical education is not devoid of humanistic ideals of education can be demonstrated from the lives of scientific workers in all ages and in all parts of the world. The joys and sorrows of these workers have a humane side in no way inferior to or less inspiring than the words of wisdom or the poetry of their colleagues who are considered the leading lights in the humanities.

While the Universities will and should continue to be the custodians of pure scientific research, the thoughtful among the Uuiversity men cannot ignore the effects of impacts of a changing civilisation on learning. The privileged position of the learned professions and the wealthy men is being questioned by labour which

was perhaps despised by these classes of people at one time. This lack of proper appreciation of all labour as important was reflected even in the academic life of the British institutions.

Not long ago, the most honoured and ancient Universities in England would have considered dentistry, dyeing or textile chemistry and even industrial chemistry as subjects unworthy of a University status. Research work on soaps, oils and fats or on stainless steel was often considered outside the scope of pure chemistry and abandoned as impure and worthy of consumption only by the labourers polytechnics. A few years ago when an enthusiast for statistical research approached the authorities of the Indian Science Congress for a place of sufficient significance for this subject, one of the leading scientists of India is reported to have opposed the idea on the ground that astrology may next claim to be a science. The Americans whose go-aheadness excites the envy of the world are neither orthodox nor sophisticated in their philosophy or academic policies. They were the first to recognise that in this civilisation based upon applied sciences education and research will have to give a suitable place to professional education and they have thus been able to give a lead to the world in chemical and radio engineering, vocational services, dentistry, industrial chemistry and even in some of the newer social sciences. Their progress has been so fast that a certain amount of criticism has been levelled against the severely practical bent of mind of some of the newer American Universities I am sure of your having read with much amusement the cynical criticism of certain American Universities for having introduced courses of studies which will lead to a Ph.D. degree in ice-cream-making or cafeteria supervision. These are perhaps exaggerated descriptions of their efforts to model University education so that it may prove helpful in providing a living for graduates in newer professions. While not advocating introduction of trivialities I am of the opinion that the Universities which are contemplating expansion should seriously consider whether courses of studies and research in aeronautics, ship-building, mineralogy, metallurgy, radio-engineering, industrial chemistry, industrial physics and hydro-dynamics are not suitable subjects for them to take up as the older Universities are so overwhelmed with financial responsibilities with respect to the pure arts and science courses that they cannot afford to take up these new and important subjects of study. I should not be misunderstood by this to mean that elementary studies of the pure science subjects is not to be undertaken by the Universities. Research facilities and provision for higher education, however, should be restricted in some of our newer Universities to these modern subjects of importance and the multiplicity of specialisation in all the pure sciences and art subjects shoule be discouraged The expansion of University activities in these directions will not only appeal to the undergraduate who feels interested in these new avenues of employment; but will also lead to the more harmonious and up-to-date growth of academic ideas and, if I am not

mistaken, more financial help from the public and the Government is likely to accrue for such undertakings. If Indian Universities had developed these subjects, Indian industry should have a different complexion at this hour of crisis in the British history.

If the Universities in India will persist in confining their attention to the usual courses of study and will neglect the newer development in which research and modern scientific methods play an important part, they will find themselves relegated to the background and replaced by other institutions more suited to this changing civilisation. As it is, learning is fast losing its importance in our University life and lesser values such as emoluments, quest for examinerships, caste and creed and party following are taking its place which threaten serious consequences to the academic standards of our educational institutions. If, on the top of all this, the Universities will not keep pace with modern developments in sciences and confine their attention only to the older subjects, they will forfeit all claims as upholders of traditions for the training of youngmen for shouldering the responsibilities of life in this complex world. It is often suggested particularly now when Europe with all its glorious achievements in the sciences is in the throes of an armament race which threatens to engulf all nations in disaster that the complexities of life are made more complex by the progress of science and that the discovery of new truths by science instead of enlarging and developing understanding, improving conditions of living and making the world a happier place for the human race is tending to do just the opposite. Even in Asia, the rising sun instead of casting its roseate hues of a peaceful dawn on the Eastern horizon is shedding blood in China for territorial acquisition and her ambitions are growing mightier and more blood-thirsty every day. Has science failed in its noble object? Does it promote unnecessary strife, unfair competition and an unwarranted sense of vainglory and vanity which must make it an inferior subject of study when compared with humanities? Such are the questions which the thinking people of the world are anxiously asking and they must be answered if the sciences are to be allowed to grow to their fullest extent. Fortunately these doubts are not allowed to play havoc with the progress of science and those great minds whose duty and privilege it is to think clearly and impartially still maintain that there is more venom in the so-called national anthems than in the deadliest poison which the organic chemist is able to manufacture. Bigotry in religion, history, faith and traditions have led to more serious acts of vandalism and harm to society than the outbreaks of fire due to heavy explosives and incendiary bombs. It is abundantly clear that the great havocs in the world, whether in the present or in the past, were not the result of an experimental demonstration of a new weapon of destruction discovered by science but were the consequences of the narrow and false appreciation of culture, country and God by men. Not much is wrong with science, but false sense of nationalism, tradition and history and

erroneous ideas of economics, empire, wealth and religion have led science inadvertantly into a strife which is certainly not the creation of the scientist.

As a matter of fact the greatest triumph of scientific education over a purely arts course of studies is that it makes students more internationally minded. The hope for the future, therefore, lies not in the scientists keeping away from a world largely the creation of the applied sciences but in his closer association with its important affairs. There has been much in the past in the world of politics which justified this policy of aloofness on the part of the scientist. The world of practical politics is essentially emotional and political controversies generally proceed with little regard for the standards which distinguish the ethics of the scientific worker. How far this detached position of science from society is justified remains to be seen. It is being increasingly felt that this civilisation which is largely the outcome of modern science needs the attention of prominent scientists. The sciences will have to create devotees who would watch the reactions which the introduction of a new invention produces on society. That scientists are seriously considering their new rôle in society and social affairs is abundantly clear from recent happenings in America, England and in our own country. The British Association for the Advancement of Science appointed a strong committee of experts to study this side of the question and the American Association and the Indian Science Congress followed them. There is no doubt that the scientific man will have to take more interest in certain aspects of society which he has neglected in the past and it is likely that the present-day politics will be benefited by this contact. Distinguished men of science such as Jeans, Eddington, A. V. Hill, Bragg, Sir Richard Gregory, Bertrand Russel, Donnan, Irvine and many others strongly feel that at least the ministers of Cabinet rank should have some appreciation of scientific method so that they may be fully fitted for guiding the destinies of a highly civilised nation in modern times.

I shall leave the task of elaborating upon the ideas of a close relationship between society and science as a whole, to others more qualified to speak with authority, but I shall touch upon one aspect of our material progress which is reflected in the birth ahd development of a child of more than ordinary promise, namely, Indian Industry. I call it a child because it is only during recent years that industry as it is understood in modern times has sprung up in India. I shall not discuss here the causes of its belated appearance, both Government and people are equally to blame and the prejudices of ages take long time to be eradicated. Science and research alone act as whips to the sluggish horses of deep-rooted traditions. But pioneers are born and not made and just as in politics and religion the tides take a sudden turn when a leader or a saint makes his appearance, so in industry a rapid fillip is given by the birth of a genius. The late Mr. J. N. Tata, whose munificence and industrial acumen are now universally recognised, gave a tremendous turn in favour of the tide of industrialisation of this country. He faced and

successfully overcame thousands of obstacles in his way and eventually brought into being some of the most successful and important industries of India and the house of Tatas is continuing and it is hoped will continue to help the development of India industrially. It is reported that when Mr Tata was putting forward his bold efforts to establish a steel and iron industry in this country, even the European experts of Sheffield and other industrial centres presented all sorts of difficulties. Alternatively the coal and iron ores found in India were considered unsatisfactory and finally when the American experts were fully convinced of the possibilities of the Indian raw materials, the interesting argument was advanced that it was impossible to have a modern metallurgical industry which requires the use of furnaces working at high temperatures in the horrid climate of tropical India. It was freely mentioned that the Indian labour could not stand the high range of temperature of a steel furnace and in the sacred name of the labourers' health, the efforts to promote the Steel Industry in India were discouraged. The perseverance and persistence of the Tatas and their determination to have this key industry in India at all costs has resulted in the coming into being of the Tata Iron and Steel Works which are now the biggest single steel enterprise in the British Empire and are helping to develop Indian industries not only round about Jamshedpore, but in the rest of India and are contributing much to the successful inauguration of modern civilisation and comforts in India. How scientific research has helped the Tatas in building up this great organisation was the subject of this year's Presidential Address at the last session of the Indian Science Congress by Sir Ardeshir Dalal and I can do nothing better than commend study of his brilliant address to those who were unable to be present in Benares. The process of development has not reached its peak as industrial development like scientific research itself is a continuous process and the Tatas are fully conscious of this fact. They have recently put up magnificent laboratories for metallurgical testing and research which are second to none in the Empire and which we hope in collaboration with the Board of Scientific and Industrial Research will help in the creation of other industries such as the manufacture of ferrous and non-ferrous alloys which are a fitting adjunct to any successful steel industry. It is a pleasing feature of the Tata enterprises that they are alive to need and usefulness of scientific research. The new chemical enterprise inaugurated by the Tatas in Mithapur will, it is claimed, result in the appointment of hundreds of chemists and it is no wonder that the research workers in Chemistry in this country are looking forward with eagerness to these new developments.

It is to be sincerely hoped that the status of the research-men and scientific workers in the industries under the Tatas will continue to rise. This is not a one-sided proposition and I cannot blame the industrialists for a different view of things if the scientific worker will not descend to the world of practical realities and will continue to unconsciously retard the successful development of industries by

his too academic an outlook on the problems of manufacture. On the other hand it must be realised that no scientific man worth the name will be able to guarantee results and fix the period for the solution of a particular difficulty or problem in industry. Patience and perseverance are as useful to the industrialist as they are to the scientist and the success of an investigation should not always be judged by the quickness of the results achieved. Oftener the more solid contributions of science to Industry take time and the established industries in the world recognise that the processes of scientific in vestigation are not black-magic. It is quite common for scores of years to be spent in developing successfully a new process which may present quite unforeseen difficulties when translated on the large scale After a judicious selection of the scientific worker, the industrialist should give him a reasonable time to show his merit. The scientific worker in industry should also realise that frequently the problems which face industry cannot stand long investigations and fancy solutions cannot be successfully exploited. A combination of commonsense with scientific acumen is what is required to solve an industrial problem.

Another industry which has developed satisfactorily and reflects great credit on Indian businessmen is the Textile Industry commonly known as the Indian Cloth Mill Industry. There are 389 mills in India with about ten million spindles and over two hundred thousand looms. While it is true that the Bombay Presidency takes the lead in this industry and over sixty per cent of the spindles and seventy per cent of the looms are located in that province, it must be mentioned that Delhi has contributed considerably to the success of this industry and the Delhi Cloth and General Mills Ltd. under the distinguished guidance of Sir Shri Ram and the Birla Cotton Mills are names to conjure with. In textile industry scientific talent is required to fill up positions such as those of engineers, weaving and spinning masters, dye and bleach house chemists and minor assistants. Research has not played such a great part so far in the present-day Indian Cotton Mill Industry. The industry, however, has chances of phenomenal development if scientific research is allowed to come to its aid. The range of its activities is already large and it is now capable of producing any grey, bleached, woven, cambric; coloured or printed cotton fabric and it touches upon some of the most important scientific investigations which are engaging the attention of workers all the world over Allied to it and in my opinion capable of being developed as a sister industry is the rayon industry. If the value of research had been appreciated in this industry earlier we should have had not only the cellulose industry with its accompaniments such as the mechanical pulp industry, but also a substantial dye-stuff industry and a variety of subsidiary industries dealing with the production of sizing materials; resins, wetting agents and chemicals and a host of other auxiliary industries such as the manufacture of bobbins, shuttles, pickers, fibre baskets, lakes, and mordants.

The rapid development of this industry and the keen competition which is likely to follow make it imperative that the attention of its promoters may be drawn to the need of scientific research in an organised manner The value of such research has been abundantly proved by the results already achieved by the Cotton Technological Institute at Matunga, but what can be achieved in the Chemical field in relation to this industry is perhaps beyond the comprehension of the lay man, but is so vast that its development may revolutionise the whole industrial outlook in this country.

I am an ardent advocate of Indian industry, not because I have any false ideas of patriotism or an intensely narrow outlook on nationalism. Nothing can promote internationalism more than a right conception of the rôle of industrial development on the world progress. I feel that India has been chosen by nature to be the industrial nursery of the world. With the wide range of climate from the rice, spices and rubber growing tracts of land of the Far South to the wheat, fruits and coniferous forests of the Punjab, Kashmir and the Himalayas in general, India is in the pride position of being able to offer to the world the widest possible selection of products which any soil can grow. To these may be added the mineral wealth of India which includes coal, iron, petroleum, building material such as stone, brick, cement, lime, pottery, tiles, and road metals, clay, gold, manganese, mica, bauxite, graphite, illeminite, monozite, chronite, Kyanite, mangasite and gypsum. The sources of cheap fuel and power are in abundance which will help in keeping down costs of production and in rendering it possible for us to have large-scale industries of any description. Cheap and efficient labour is also easily available and the adaptability of this labour to changing industrial conditions is another worthy feature of our natural advantages as a nation capable of industrial development. Leaving political factors aside, it is the neglect of applied sciences and lack of our ability to organise which have stood in our way and delayed the march of progress in the industrial field. It will be a blot on us and a spurning away of the offer of the bounties of nature and God, if we are unable to harness all our natural advantages for the emancipation of our people and the world.

Coming to another industry which has had a phenomenal growth, namely, the Sugar Industry, I find that the conditions of scientific workers and research in some of the sugar factories are still appalling. The chemist has the status of a daily wage-earner and comes and goes with the cane crop. He is more often poorly paid and as profits can be made easily and the scientific testing has been rendered fool-proof by research, the capitalist has not much use for the chemist. There is some evidence of a change of outlook in some of the bigger concerns, but with the new conditions which have arisen, research will probably be able to establish a position for itself. If the sugar industry is to live, new uses must be found for surplus sugar, the bye-products must be utilised and the molasses and bagasse should be made to yield more income than they do at present. In this connection, I wish to draw the attention

of those who are interested in the Sugar Industry to two or three uses to which molasses can be put with advantage particularly at this time.

1. The most important of these as a war measure is the production of acetone from molasses by bio-chemical fermentation. As acetone has only limited commercial possibilities at present in India and is largely a war material used in the production of ammunition, Government will have to give some sort of protection for the manufacture of acetone and butyl alcohol from molasses. The latter has some market but the former is useful in large quantities only in ammunition production and the demand at present must be large indeed. The successful inauguration of this venture will depend upon Government participation and the Sugar manufacturers should take active steps to interest the Government.

2. Another good use to which molasses can be put is its conversion into food on the yeast basis. By suitable combination of vegetable-oilseed-proteins and molasses, it is possible to obtain yeast food containing easily assimilable proteins and vitamins so urgently required for a population which cannot afford meat or will not take animal proteins owing to religious or social prejudices. Professor Wilstatter made an extensive study of the subject and such foods are now being commonly used in Germany. I will not be surprised if after the war Germany admits her ability to have continued the war without meat foods owing to these developments. The introduction of a new food for the masses of India is not an easy proposition, but these products can be mixed with flour and as they are perfectly vegetarian in character and quality and of good taste, it may be possible to introduce these foods gradually with great advantage to the poorer classes for whom suitable nutrition is an urgent necessity.

3. Bio-chemical research has made it possible to convert molasses and starches into useful hydrocarbons and into alcohols and ketones. Both molasses and starch are available cheaply in this country and it will be interesting to produce these materials for mixing with fuel oils. Ketones particularly have been described to be very efficient in increasing the anti-knock value of petroleum fuels and the possibility along these lines promises a fruitful field of research which will be of immense value to the country and which may save the sugar industry from the disaster which faces it at present.

I have briefly indicated these as illustrations of what research can do to help industry when it is at the zenith of its glory or when it is faced with prospects of extinction owing to changing conditions due to political strife or over-production. Industrialists, scientists and the Government in England are already beginning to feel the acute need of scientific men who will help them in converting some of the war industries into machines for the manufacture of commodities useful in peace times. This will no doubt constitute a definite plan of industrial reorganisation after the war and the industrialists in India should familiarise themselves with the technique likely

to be followed up and the students of science should study this important subject with care.

It is strange that even in the year 1941 people should suggest that the Universities should direct their attention only to theoretical research and should not participate in industrial research for indigenous industries. These too ardent advocates of industrialisation propose that the Board of Scientific and Industrial Research should encourage industrial research by grants of subsidy only to industrial concerns and industrial research organisations and not to the Universities. These proposals hardly merit any attention as they are based on the wrong assumption that the Universities are incapable of doing industrial research. When this Department was founded in England its main function was to correlate and co-ordinate research activities wherever they existed and to help industry by advising as to where their problems could be best solved. That the Universities were brought into the closest co-operation with industries by the Department of Scientific and Industrial Research is abundantly clear from the fact that during the years 1919—1921 when I was at the University College, London, at least two groups of industries had their research headquarters at University College, London. One of these groups was the rubber manufacturers' association headed by Dr. Fry and the other group consisted of the photographic goods manufacturers' association headed by Dr. Slade who now occupies a prominent position with the Imperial Chemical Industries and both these schemes were housed in the University College. I myself was one of the earliest research scholars of the Department of Scientific and Industrial Research at the University College because my work on emulsions had an industrial bearing.

I am all for the development of research associations, but the Universities should not and cannot be divorced from industrial research activities. First-rate industrial research can only come from one who is a first-rate research worker. Problems of routine character should not interest a great worker, but new uses for raw materials, new processes, new machines, and new methods of investigation require the highest intellect.

Science and industory go hand in hand and any attempt to divorce them will lead to an unsatisfactory and unhappy state of affairs. Fundamental research helps industries, but problems of fundamental interest are also suggested by industry. Hundreds of examples of this can be cited. Langmuir's classical work on theory of absorption and surface orientation was carried out in the research laboratories of the General Electric Company at Schenectady. Here is an example of an important contribution of theoretical research from the laboratories of an industrial organisation. Examples of Universities and educational institutions contributing to researches which have led to industrial development are so many that it is possible to write a whole book on the subject. It would suffice here to mention a few of the prominent examples. Perkin's work on magenta led to the establishment of the first dyestuff factory in

England. Here the discoverer himself became the manufacturer. Mercers' work in the Sorbonne at Paris resulted in the establishment of the manufacturing processes for mercerising cotton Sir James Dewar's researches at Cambridge perfected the Dewar's flask, the precursor of the Icy-hot bottle and dry ice which have revolutionised the modern refrigeration industry. Haber's work in the Kaiser Wilhelm Institute of the Berlin University on the fixation of nitrogen gave birth to the now famous Haber process. The Nernst filament lamp was developed by Professor Nernst in the Berlin University. At Munich, Dr. Franz Fischer's researches gave birth to the industry now well known as the low-temperature carbonisation of coal Has not the Sheffield University contributed to Industrial Research in steel and glasses and the Manchester in colour and textile chemistry and their technical applications.

No hard-and-fast lines can be drawn between pure and applied research. What is pure research today may become applied tomorrow and it is necessary for the Universities to have an all-round programme of pure and applied research. As to what special form a man's intellectual activities will take depends upon the man's own inclinations and capabilities for, after all, it is the man that matters. The desire which should animate the mind of every scientist is search for truth and service and the real man will develop in the way in which he can serve best.

It is wrong on my part to deliver a presidential address to the Chemistry, Physics and Mathematics section of so little use to the mathematician and theoretical physicists present here in such large numbers and of whom your illustrious President, Sir Shah Sulaiman, and Doctor Kothari are the local representatives. Mathematics has enabled sciences to be systematised and the precision of a scientific measurement is not confined to its expression in mathematical units. Precision in science has its direct origin in Mathematics. Without this precision no application of science could have succeeded in producing its beneficial effects on mind and society and whatever may be the truth in the saying that Mathematics is a good slave to science but a bad master, I cannot help feeling that a combination of Physics, Chemistry and Mathematics forms a really good basis for the education of one who wishes to take up scientific research as a career and Mathematics is by no means the least important in this combination. It is in my opinion the most useful. As chairman of this section, it will be my endeavour to give Mathematics her rightful first place in the academic discussions which will now follow.

Abstracts of Papers Communicated

Steller Configurations *By A. C. Banerji*, Mathematics Department, Allahabad University.

The gravitational energy and the heat energy of a star are quite inadequate to account for the emission of energy which is going on more or less at a steady rate for an interval of at least 10^7 years without much change in the type of the star. It is possible that the transformations of matter into radiation by means of atomic transformation is the main source of supply. Fowler has calculated

and Eddington has corroborated that for the cold degenerated gas the equation of state is given by $p = c\sigma^{\frac{5}{3}}$ where σ is the electron density. Eddington has further shown that Stoner-Anderson relativistic degeneracy formula is untenable. Up to a first approximation we may perhaps assume that the perfect gas law will hold good for ordinary Steller material, and that Fowler's degenerate gas law will hold good for the material in white dwarfs. The following problem needs consideration :—

A spherical distribution of gaseous matter of mass M and known chemical composition and in steady state of luminosity L is given, it is required to find the internal distribution of density and temperature and its external radius. First it is necessary to search out the agency which would supply a star with output of energy representing its luminosity. We have to make sure that :—

(*i*) This agency must be capable of maintaining almost a steady state for a sufficiently long time and should not cause any instability.

(*ii*) It should be operative in material of moderate density which is in thermodynamical equilibrium at temperature of about 10^7 degrees.

(*iii*) It should be instrumental in explaining the difference between Giants, Main Sequence stars and White Dwarfs.

Now relativity teaches us that emission of certain amount of energy would involve the loss of proportionate amount of mass. It is an experimental fact that under certain conditions where a hydrogen nucleus (proton) collides with a heavier nucleus it may penetrate the latter, then either it would form a single new nucleus or split into two new nuclei both being more complex than hydrogen. Such a process would result in the disappearance of about ·008 of its mass which is equivalent to $1{\cdot}2 \times 10^5$ ergs and which is transformed into the kinetic energy of the nuclei or into energy of an ejected γ or β particle. Within a star this energy is likely to re-appear as ordinary heat energy or radiation.

In this connection Bethe's classical work on nuclear transformation may be referred to. Bethe has shown that the only important basic reactions worth considering are the combination of two protons to form a deuteron which then captures another proton to become He^3 and also the ultimate combination of 4 protons to form into an 'α' particle He^4. This process yields about 2·2 ergs per gram per second under standard steller conditions. There is a second process in which the ultimate net result is the formation of an 'α' particle with the restoration of c^{12}. So heavier nuclei function solely as *catalysts* to produce helium. This latter process is estimated to yield about 100 ergs per gram per second under "standard steller conditions." The only appreciable permanent hypothesis which can occur in a star is the formation of helium from hydrogen. Other nuclei lighter than those having atomic mass less than 12 cannot exist as permanent product under steller conditions. All nuclei heavier than atomic mass 12 are conserved though some act as catalysts in helium production.

To determine steller configuration we can therefore assume a polytropic law of the form $p = \kappa\rho^{1+\frac{1}{x}}$ in the absence of any rotation or any other disturbing factor, an isolated mass of gas will assume a spherical shape due to its own gravitation. If this gaseous mass begins to rotate about an axis the shape can no longer be spherical. For a small angular rotation Milne and Chandra Shekhar have obtained approximate solutions. Now the angular velocity of a star cannot be uniform throughout and its inner part must rotate more rapidly than its surfaces. So Bhatnagar has considered the case for which

$$\omega^2 = \omega_0^2 \left\{ 1 - \alpha \frac{r^2}{R^2} (1 - \mu^2) \right\}$$

where R is a constant equal to or greater than equatorial radius of the star, and α is some numerica constant.

P. L. Bhatnagar has shown dynamically that if there is an encounter or even grazing encounter between two gaseous stars, no planetary ribbon can be formed. If there is actual clash, the result will be far too catastrophic to investigate. Dr. Spitzer has shown from thermodynamical consideration that even if a planetary ribbon is formed it will dissipate away immediately. It appears that pulsation of a star in addition to its rotation may have something to do with the formation of its planetary system. It can be mathematically shown that when a pulsating spherical star becomes spheroidal due to rotation, pulsation would ultimately die away and in some cases before the pulsation ceases some material due to instability or resonance phenomenon would be thrown out, and planets might be formed out of this ejected material.

ON FUNCTIONS WHICH ARE FOURIER SINE OR COSINE-TRANSFORMS OF EACH OTHER. *By Hari Shanker*, Anglo-Arabic College, Delhi.

The object of this paper is to prove the following Theorem :—

$$\text{If } \phi(x) = (2\pi)^{-\frac{1}{2}} \Gamma(m+1) D_n(x) \left\{ e^{i\mu\pi} D_{-m-1}(ix) + e^{-i\mu\pi} D_{-m-1}(-ix) \right\}$$

and $$\psi(x) = n!\, e^{-\frac{1}{2}x^2}\, x^{m-n}\, L_n^{m-n}(x^2)$$

then $\phi(x)$ and $\psi(x)$ are Fourier Sine or Cosine-transforms of each other according as $\mu = \frac{n+1}{2}$ or $\frac{n}{2}$ where 'n' is a positive integer and 'm' is any number greater than '$n-1$'.

ON THE GEOMETRY OF REAL FORMS. *By S. M. Kerawala*, Muslim University, Aligarh.

Protagoras was one of the earliest to challenge the truth of Euclidean geometry when applied to real forms. The early geometers ignored the challenge completely, but of the few that did give some thought to it may be mentioned Helmholtz, Pasch, F. Klein, Poincaré, and Hjelmslev. A system of axioms has been formulated by Hjelmslev, which may be relied upon to give results consistent with reality and experience. But to be perfectly logical, Hjelmslev had to build up his geometry on a purely empirical basis. If rigour, however, be relaxed a little, a new and interesting outlook of this geometry is obtained. In the present paper, an attempt has been made on these lines to do homage to the genius of Protagoras.

TABLES OF MONOMIAL SYMMETRIC FUNCTIONS IN TERMS OF POWER-SUMS. *By S. M. Kerawala*, Muslim University, Aligarh.

Considering the use of symmetric functions in statistics, tables of monomial symmetric functions of weight up to 8 have been calculated by O'Toole and Sukhatme. Recently, M. Ziaud-Din has published the table for weight 9. As there are a number of mistakes in the last table, I have calculated it afresh and have added to it the table of weight 10. Further, I have developed in this paper formulæ for the rapid calculation of the weights of higher orders.

ON THE FERMI-DIRAC FUNCTIONS. *By F. C. Auluck*, Dyal Singh College, Lahore.

A new method is given for evaluating the integral $\int_{\sigma}^{\infty} \frac{\varphi'(x)}{e^{x-t}+1}\, dx$ where $\varphi(x)$ is any function of x.

THE VARIATION METHOD FOR THE DIFFERENTIAL EQUATION IN η VARIABLES. *By M. R. Siddiqi*, Osmania University, Hyderabad-Deccan.

The equation $\sum_{r=1}^{n} \frac{\partial}{\partial x_r}\left(p\, \frac{\partial u}{\partial x_r}\right) - qu = f$, for various boundary conditions, is transformed into various problems, and hence the existence and uniqueness of the solution is established. The method is also extended to the equations of higher orders.

SHORTER AND QUICKER METHODS FOR LONG MULTIPLICATION, DIVISION, DECIMALISATION, SQUARE ROOTS & DIVISIBILITY TESTS. *By R. S. Mukand Lal*, Government College, Lahore.

Long multiplication can be done mentally and quickly by re-arranging the multiplier by inverting it about its units digit, for, then the constituents of different columns can be obtained by *parallel* multiplication, instead of by *crosswise* multiplication of the classical method.

Long division is reduced to short division by the first digit of the divisor, by retracing the steps of the original multiplication work *column-wise*, and not row-wise as in the classical method. At each step the partial dividend has got to be *corrected* by subtracting the sum of parallel partial products of the *other* digits of the divisor reversed and an equal number of the digits of the quotient last obtained.

The new method of long division has given rise to amazingly rapid methods for decimalising proper fractions whose denominators be of form $10^r S \pm 1$, when r is any positive integer, and S a simple number below 20 or some such number as 21, 31, 30, 40, 50, etc.; that is, a number by which short division is possible. The first r digits of the quotient can be obtained by dividing the numerator by $10^r S$. These r digits then give rise to the next r digits of the quotient, which in their turn give rise to the next r digits, and so on.

The new method of *columner* multiplication has given rise to a neat method of finding square root, whose eight to ten digits can be written down by easy mental calculations after a little practice. The new method reduces itself to one like short division, the partial-dividend, so to say, to be corrected by means of the "*end-to-end products*" of the digits of the square root obtained at any stage.

The universal test for divisibility applies to all odd numbers. But the test becomes *mental* when the odd number ends in 1 or 9 and is less than 200, or if it ends in 3 or 7 and is less than 100. The classical mental tests for divisibility by 3, 7 and 9 are particular cases of this universal test of divisibility by all odd numbers.

SOME PROPERTIES OF RECTILINEAR CONGRUENCES. *By Ram Behari*, University of Delhi.

In this paper rectilinear Congruences which consist of a system of lines parallel to a fixed direction have been considered, and some properties of such congruences have been obtained analytically.

A CERTAIN CONFLUENT HYPER-GEOMETRIC FUNCTION. *By B. Mohan*, Mathematics Department, Hindu University, Benares.

The paper aims at deducing certain properties of a confluent Hyper-geometric function. For instance, if

$$\phi_\nu(x)=\frac{(\frac{1}{2}x)^\nu \sqrt{\pi}}{\Gamma(\nu+1)},\ F_1(\tfrac{1}{2};\nu+1;-\tfrac{1}{4}x^2),$$

it is shown that

$$\phi'_\nu(x)=\phi_{\nu-1}(x)-\frac{\nu}{x}\phi_\nu(x),$$

$$\left(\frac{x}{2}-\frac{\nu}{x}\right)\phi_\nu(x)=(\nu+\tfrac{1}{2})\phi_{\nu+1}-\phi'_\nu,$$

$$\phi''_\nu+\left(\frac{x}{2}+\frac{1}{x}\right)\phi'_\nu+\left(\tfrac{1}{2}-\tfrac{1}{2}\nu-\frac{\nu^2}{x^2}\right)\phi_\nu=0$$

$$\left(\frac{d}{2dx}\right)^m\left(x^n\phi_n\right)=x^{n-m}\phi_{n-m},$$

$$\phi_\nu(x)=\frac{(\frac{1}{2}x)^\nu}{\Gamma(\nu+\frac{1}{2})}\int_0^1\frac{t^{\nu-\frac{1}{2}}}{\sqrt{1-t}}e^{-\frac{1}{4}x^2(1-t)}dt,$$

and

$$\int_0^\infty x^{p-1}e^{-ax^2}\phi_\nu(bx)\,dx=\frac{b^\nu\Gamma(\frac{1}{2}p+\frac{1}{2}\nu)}{2^{\nu+1}a^{\frac{1}{2}p+\frac{1}{2}\nu}\Gamma(\nu+1)}\times F\left(\tfrac{1}{2},\tfrac{1}{2}p+\tfrac{1}{2}\nu;\nu+1;-\frac{b^2}{4a}\right).$$

ELLIPTIC SOURCES AND VORTICES. *By Prithi Nath Sharma*, Hindu College, Delhi.

It is well known that any motion, irrotational or rotational, can be obtained by a system of sources, sinks and vortices suitably placed in the fluid. In general, excepting the case of circular boundaries, this system is not a simple one. In fact the simple case of an elliptic cylinder moving uniformly through a liquid requires an infinite number of sources and sinks. But, if we develop the idea of an elliptic source, we can shew that this uniform motion can be produced by only an elliptic doublet. In this paper results connected with elliptic boundaries have been obtained very easily by using elliptic sources and vortices.

EFFECT OF COMPRESSIBILITY ON THE LIFT OF AN ELLIPTIC CYLINDER. *By B. R. Seth*, Hindu College, Delhi.

The effect of compressibility on a body placed in a uniform stream of fluid moving with a speed U less than a_0, the velocity of sound, has been discussed by various investigators. Janzen has discussed the case of a circular cylinder and Rayleigh that of a sphere by assuming U to be small compared with a_0, the motion now being almost the same as if the fluid were incompressible. Taylor has developed a mechanical method based on the analogy between the flow of a compressible fluid and the flow of electricity in a sheet of variable thickness.

Prandtl and Glauert have explored this effect on the flow around thin airfoils by assuming the variations in velocity to be small compared with $U-a$ method used by Oseen for viscuss flow. This they have done by assuming a single vortex filament in a uniform flow. In this paper we discuss the effect on the lift when an elliptic cylinder having circulation is placed in a uniform flow.

Time Periodicities in Cosmic Radiation. *By P. S. Gill*, Forman Christian College, Lahore.

With the data from the Carnegie Institution's Model C cosmic-ray meters at four widely separated stations, a study of various time periodicities was made. The amplitudes and phases of yearly and half-yearly periods were calculated, and a study of variations of cosmic-ray intensity with a 28-day period was also made. Data from one of the stations (Teoloyucan, Mexico) were analysed for daily changes both with respect to solar and siderial time. At Teoloyucan a 12-hour period is found to be more prominent than the 24-hour period. The amplitude of the first annual harmonic with a maximum in colder months has a higher value at higher latitudes than that at lower latitudes.

Measurement of the Angle of Incidence at the Ground of Downcoming Short-waves from the Ionosphere. *By Chaman Lal*, All-India Radio Station, Delhi.

Measurements of downcoming angles for a number of European short-wave stations have been made. The apparatus consists of two commercial super-heterodyne receivers with two parallel horizontal dipole aerials for picking up energy. Downcoming angle is inferred from the phase difference between the voltages on the two aerials.

Average value of the downcoming angle for the B.B.C. transmitters during the months of May, June, September and November, 1940, came out to be 16°, 20·6°, 15·2° and 14·2° respectively.

The average values obtained for the German stations for the month of May, June and November, 1940, came out to be 20·8°, 19° and 15°.

The relation of Gas pressure to Radiation pressure in Bose-Einstein gas. *By B. N. Singh and A. G. Chowdri*, Physics Department, University of Delhi.

In this paper we have studied the variation of the ratio, δ, of the gas pressure to radiation pressure in Bose-Einstein gas. It has been found that when δ is less than unity the gas is necessarily non-degenerate but the converse is not true, *i.e.*, in a non-degenerate gas δ may be less than or greater than unity.

In degeneracy, δ must be greater than unity in non-relativistic case. In the degenerate relativistic case δ is identically equal to unity, *i.e*, the gas pressure is always equal to radiation pressure.

Sensitiveness of the Optical Hygrometer and the Effect of Time on it. *By L. D. Mahajan*, Patiala.

In this paper, the construction of the optical hygrometer and the modifications made therein are described in detail. The theory and its working is explained. Various conditions which make it more sensitive have been discussed. Its sensitiveness has been compared with that of other kinds of hygrometers.

The effect of time and the minimum period of time required to effect its readings have been studied and various curves have been drawn to represent the relation.

THERMODYNAMICS OF DEGENERATE FERMI-DIRAC GAS. *By B. N. Singh and D. S. Kothari*, Physics Department, Delhi University.

The properties of a free electron gas, neglecting the effect of relativity mechanics, have been studied in detail by Stoner and others. However, the relativistic correction becomes of importance in astrophysics, and, in this paper, general expressions for the thermodynamical functions representing the Energy, Entropy, Pressure, Gibbs Free-Energy, Helmholtz free-energy, Total Heat and Specific Heat at constant volume are derived to the second approximation taking account of the effect of relativistic mechanics. The results are expressed in terms of the non-dimensional quantities.

$$x = \left(\frac{3n}{4\pi g}\right)^{\frac{1}{3}} \frac{h}{mc} \text{ and } y = \frac{mc^2}{kT},$$

where n is the concentration and m the mass of the particles, h the Planck's constant. k the Boltzmann's constant, c the velocity of light and T the absolute temperature. By making $x \to 0$ and $x \to \infty$, we obtain, in the limit, the well-known expressions for the completely non-relativistic case and the completely relativistic case respectively.

THE SOURCE OF ENERGY IN A WHITE DWARF STAR. *By D. S. Kothari*, Physics Department, Delhi University.

A white dwarf star is characterised by a very low luminosity and an abnormally large density. The recent work of Wildhack and others deals with the energy generation due to the null-point velocity of the protones. In the present paper it is shown that gravitational contraction can account for the energy liberation of a white dwarf.

EFFECT OF AGEING ON THE VISCOSITY OF SOME SOLS. *By S. Jha and S. Ghosh*, Chemistry Department, University of Allahabad.

The changes of viscosity on the ageing of sols of one concentration and purity have been investigated by a number of workers. The results presented in this paper, on the measurement of viscosities for the sols of stannic hydroxide, ferric phosphate and vanadium pentoxide, obtained at their various stages of dialysis and different dilutions, carried out at variable shearing forces, lead to the conclusion that the effect of ageing on the viscosity of the sols is intimately related with the purity and the concentration of the sols. The general conclusions of this investigation are as follows :—

1. The viscosity of a concentrated sol increases on ageing and reaches a maximum value, which is followed by a decrease.
2. The viscosity of a dilute sol decreases at first and then there is an increase followed by a decrease.
3. Where there is an increase in the viscosity of sol, it passes through the maximum value more quickly for dilute and pure sols than that in the case of concentrated and impure ones.
4. Changes in the viscosity of a sol with ageing are more with concentrated sols than with dilute ones.

5. For some of the measurements, higher the pressure, lesser are the changes in viscosities of sol with ageing.

6. It is concluded from the results obtained in this paper that the sols generally tend to decrease in viscosity with age. If, however, the sol shows "*structural flow*" there is an increase in viscosity to a maximum followed by a decrease with time.

CHEMISTRY OF VITAMIN E. *By R. H. Siddiqui*, Chemistry Department, Muslim University, Aligarh.

Evans reported the presence of vitamin E in 1922. The vitamin was named subsequently by George Calboun as α-tocopherol. The actual isolation from wheat germ oil in a state of purity was achieved in 1936. In the following year β-tocopherol was isolated and in 1938 these molecules were subjected to intensive chemical examination as a result of which their constitution was established and was confirmed by synthesis. In 1939 the lower homologues with α-tocopherol-like activity were synthesised.

ISONITROSO-MALONYL-GUANIDINE. A CORRECTION. *By Sikhibhushan Dutt*, Chemistry Department, Allahabad University.

Contrary to a previous report, it has now been found that Isonitroso-malonyl-guanidine does not form stable salt with organic bases. The previously prepared salts have now been found on close examination to be mixtures.

STUDY OF SUPER-SATURATED SOLUTIONS BY DILATATION METHOD. *By Ram Gopal*, Chemical Laboratories, Lucknow University.

In a paper (Proc. of the Academy of Sciences, U. P., Vol. 1, December 1931) Nayer studied super-saturated solutions by dilatation method and found that there occur two inflexions (the first one at the saturation point and second when the release of super-saturation takes place) in the temperature-volume curves.

Van Hook (Journ. Phy. Chy., Vol. 41, P. 593, 1937) studied super-saturated solutions by the same method and found that temperature dilatations curves of super-saturated solutions show "no non-uniformity at the saturation point."

In the present paper dilatation method has been employed as was done by the above workers to study the super-saturated solutions of a number of salts in water.

Aqueous solution of different salts saturated at temperatures between 50°–70°C were put into dilatometer after filtering so as to remove any trace of dirt or other nuclei that may be present in the salts. The dilatometer was dipped in a beaker containing hot water and this could be slowly cooled. The rate of cooling was controlled by keeping a micro-burner under the beaker. The rate of cooling was so adjusted that it took about an hour to lower the temperature by 10°C. As the solution was being cooled, the readings on the scale were noted.

In these cases in which crystallization occurs, there is a change in the direction of the curve at the point of crystallization. The magnitude of inflexion is dependent on the quantity, *i.e.*, the amount of crystals formed on release of super-saturation. In case of oxalic acid temperature rises, but in $NaNO_3$ and KNO_3 no rise is noticed at this point, only cooling slows down a bit.

In the case of sodium acetate, a substance which is capable of remaining in super-saturated state to a great extent, no crystallization took place even when $-8°C$ was reached, the saturation temperature being $58°C$. If crystallization is induced at this temperature by adding a minute crystal of sodium acetate, the release of super-saturation occurs at once and the mass sets as a whole. The temperature rises to $36°C$, but no scale-reading could be taken as in attempting to inoculate, the oil was disturbed. It is, however, clear that sodium acetate does not crystallize within the limits of the temperature tried and no break in the curve was observed.

From the curves it can also be seen that inflexion is well marked in the case of oxalic acid, not so clear in the case of sodium nitrate and does not occur at all in the case of sodium acetate. This may be due to the fact that comparatively large amount of crystals are released in the case of oxalic acid as temperature coefficient of solubility of oxalic acid is higher, whereas in the case of sodium nitrate the quantity released is small because temperature coefficient of solubility is low. In the case of sodium acetate there is no inflexion as no crystallization occurs in this case.

We are, therefore, of opinion that the inflexion at the saturation temperature observed by Nayer was merely due to crystallization that sets in at that temperature, and if the crystallization of oxalic acid can be stopped somehow the inflexion observed by us at the point where release of super-saturation occurs, will also disappear or at least shifted to some lower temperature where crystallization may set in. On the other hand, if crystallization of sodium acetate solution can be brought about, we should get a graph similar to that of oxalic acid type. Further work in this direction is in progress.

Section B.—Botany, Zoology, Agriculture and Geology

PRESIDENTIAL ADDRESS

RECENT DEVELOPMENTS IN THE SCIENCE OF PLANT AND ANIMAL NUTRITION AND THEIR SIGNIFICANCE TO NATIONAL NUTRITION AND HEALTH

By B. Viswa Nath

Director and Imperial Agricultural Chemist, Imperial Agricultural Research Institute, New Delhi

The researches in the field of nutrition and health in the past two decades have led to the view that much of the poor physique and varying degrees of ill-health of the people can be traced to inadequate or faulty diet or to its defective chemical composition. Wide-spread interest is evinced in diet reform and in crop production for more and better nutrition.

In recent years there have been published results of researches which throw new light on the relationship between plant and animal and human nutrition. The trend of recent research and thought is to associate plant nutrition with animal nutrition in a new way. These developments, besides being of considerable interest to plant physiologists and agricultural chemists, are of value to practical agriculture.

1—Plant is the Chief Source of Nutrition and Energy

A common characteristic of all living things is the ceaseless ebb and flow of energy which is constantly being exchanged with their environment This is the motive power by which inorganic material is constantly being fashioned into organic material, which, after passing through successive changes and after having displayed various manifestations of life, is ever returning into the inorganic, only to assume again the organic form. That is the great round of energy in the plant and animal kingdoms, with the soil and the life in it as the intermediaries In fashioning their own structures, plants are continually availing themselves of the sun's light energy, giving birth to substances of diverse composition and quality, which are to constitute the materials necessary for the life of animals and human beings, who, unlike plants, are powerless for building up their bodies from inorganic salts, water and the atmosphere.

Plants, therefore, are the chief sources of nutrition and energy for human beings and animals. The stem, leaf, fruit and grain are either eaten direct or they

may be first eaten by the animal and its milk or flesh is afterwards consumed by human beings and animals. It, therefore, follows that it is the ability of plants to manufacture food and the right kind of it that is important in nutritional economy. Plants absorb water and certain mineral constituents from the soil, and in the presence of sunlight and atmosphere prepare such compounds of potential energy as proteins, carbohydrates, oils and fats, vitamins and other organo-mineral compounds. When these compounds are eaten by human beings and animals, the potential energy stored by plants becomes available for growth, movement and maintenance of health.

2—Development of the Knowledge of Foods and Diet Standards

In the early days of the science of nutrition, the energy or the calorigenic value of food derived from proteins, fat and carbohydrates was all that was thought necessary in a diet, and certain proportions of these constituents and water were fixed for various diets. As knowledge of the chemical nature of the foods developed, it became apparent that a mere study of the total calorie or protein requirements for a diet presents but a feeble view of the complexity of the processes of digestion and assimilation, and that minute requirements of certain mineral salts and accessory food factors, known as vitamins, and their nice adjustments were involved.

A further advance is that all proteins have not been found to be of equal biological value, and that this value varies with the nature and amino-acid make-up of the proteins. The knowledge that amino-acids are the building stones for the protein molecule, and that animals and human beings are unable to synthesise these acids in their bodies but have to be given these in a pre-formed state either as plant protein or milk or flesh protein of the animal that eats the plant, as also the knowledge that all amino-acids are not of the same nutritive value and that all vegetable foods and feeding-stuffs do not contain all the necessary amino-acids, opened up fresh fields of enquiry into the composition of plants and their products.

It has been established, after the discovery of vitamins, that the animal kingdom depends on the plant kingdom for the supply of vitamins, and that vitamins found in animal products such as milk have their origin in the plant. Indeed, even the famous cod liver oil owes its vitamin A content to the plant world. Drummond and Zilva have traced the source of vitamin A in cod liver oil to the minute chlorophyllaceous diatoms which float on the surface of the sea. All plants and all parts of plants have not been found to contain all the vitamins or in equal quantities, and this has led to a feverish search of the plant kingdom for the nature and content of vitamins in food plants.

3.—Relationship Between Plant Nutrition and Animal and Human Nutrition

We see around us the marvellous natural phenomena that, from the same soil and the same moisture and nutrients it contains, plants of different races, forms and composition develop. We attribute this to the individuality of the seed. A given seed always develops a plant of its own kind. This mysterious performance of the seed is considered to be fixed and unalterable. Recent research has, however, enabled us to induce mutations under the influence of X-rays and certain chemicals. Fertilisers and manures are believed to act only in accelerating growth and in increasing the size of the plant, and lack of that nutrition to the plant results in stunted growth. Although it is known that the plant is directly or indirectly the source of food for animals and human beings, it is not considered that if the plant is unable to have the conditions and nutrients necessary, it cannot grow and develop fully, and that the composition of the plant must be affected by the nature and extent of the deficiency and to that extent influence the nutrition of animals and humans.

The obvious association and the inter-relationship between plant nutrition and animal and human nutrition have, however, been known and recognised only partly. The effect on animal nutrition of deficiencies in plant nutrition in respect of major and minor or trace elements or minerals has been known and recognised. Otherwise it is generally believed that the composition of plants is fairly constant, and nutritive values are calculated and diet standards are fixed on the basis of the proximate organic and ultimate mineral composition of plants and their products. It was not known till recently that the environmental conditions and particularly the nutritional conditions available to the plant are capable of exercising an influence on the metabolic processes in the plant leading to changes in its composition and nutritive value. Even if the gross composition of the plant is not found to vary, the finer composition and the biological value of the constituents may be altered, leading to variation in the biological efficiency of the plant produce.

This has been so because, since the advent of Liebig's mineral theory of plant nutrition and the development of the science of plant nutrition in the wake of that theory, the advances in plant physiology and chemistry of crop growth have been closely associated with the technique for the application of mineral fertilisers. The development in the latter have been followed by progress in studies on the metabolism of major and minor elements in plant nutrition on soils rich in organic matter in the temperate regions. Another reason is that the bewildering expansion in these sciences necessitated such intense specialisation that advanced studies in plant and animal physiology and nutrition have had to proceed separately among groups of workers in different laboratories, with the result that complemental studies have

not been possible and basic principles which underlie related phenomena have been missed, and the reactions of animal and plant life have tended to emphasize diversity rather than unity in the essential principles underlying the biochemical mechanism of all life. As one writer in a recent number of the British Medical Journal has put it, "wisdom has been placed on the periphery which has been expanding so rapidly that investigators have almost lost sight of the centre."

4 - Newer Knowledge of The Relationship Between Plant and Animal Nutrition

I have had the good fortune to secure the collaboration of Lt.-Colonel R. McCarrison (now Major General Sir Robert McCarrison), then Director of Nutrition Research, Coonoor, and to carry out complemental studies in plant and animal nutrition in the years 1925 and 1926. Since then myself and my associates have been engaged in investigations on the nutritional relations between plants and animals, with special reference to the role of organic manures in plant nutrition and in relation to animal and human nutrition. My interest in this aspect of the subject was aroused from three facts:—firstly, in several cases the performance of organic manures like cattle or farmyard manure, composts and such others could not be explained in terms of nitrogen, phosphoric acid, potash and organic matter they contained; secondly, practical agriculturists and horticulturists look upon organic manures, especially cattle manure, with traditional esteem and reverence; and, thirdly, on Indian soils mineral fertilisers are more efficiently utilised by crops in the presence of organic manures than when used alone. It occurred to me that here was a case that could not admit divorcing of tradition without investigation of the physiological significance which might not have been recognised.

The studies on the nature of action of organic manures and mineral fertilsers on plant metabolism and through the plant on animal metabolism, have shown that environment and fertiliser and manurial treatment can exert a profound influence, previously unsuspected, on the course of plant nutrition and through the plant on animal nutrition. The investigations on the role of organic matter in plant nutrition are of value in that they have broken new ground.

In these studies a number of people have been associated with me. Messrs. P. V. Ramiah, M. Suryanarayana, P. Satyanarayana and K. Bhushanam worked with me in the early years at Coimbatore, and later at Delhi Messrs. P. Satyanarayana and N. G. C. Iyengar were associated with me. With their assistance several aspects of the problem have been investigated. For the first time a complete picture of the cycle of factors in the system soil-plant-animal was presented in 1926.

The conclusions from the results of the experiments published fifteen years ago were :—

1. Manuring influences the quality of the seed;

2. Manuring influences the nutritional value of the crop ;
3. Plants require accessory food factors like vitamins for animals and organic manures have as one of their functions the supply of the accessory factors ; and
4. In nature a cycle of accessory factors operates through soil-plant-animal including human beings.

These findings were new and contrary to the prevailing ideas on the subject. Our knowledge then was incomplete, and the limited experience naturally caused difficulties in getting clear of the prevailing view points. In the year that have elapsed more data have been obtained in India and outside. It will, therefore, be of interest to review in some detail the developments since then, and discuss the significance of the newer knowledge to crop production for national nutrition and health.

5—The Influence of Nutrition to the Mother Plant on the Quality of the Seed Material

Viswa Nath and associates (1926, 1927, 1931, 1932) have shown that manurial and fertiliser applications are capable of reacting on plants, not only by increasing growth and yield but also by influencing the quality of the seed with regard to its capacity for subsequent crop production. When seeds from crops grown with different manures were sown in a soil of moderate fertility the resulting crops were different and varied with the nature of nutrition the mother plant had. They have also shown that plants absorb nutrients most when they are young, and that seedlings raised in a properly and well manured seed bed grow better when transplanted into an unmanured soil than those grown in a poorly manured seed bed.

Kruger (1927, 1928) and Kottmeier (1928) report that the quality of seed potato is influenced by manuring. The worst quality of seed was obtained with physiologically alkaline fertilisers like calcium cyanamide, sodium nitrate and potassic manures, while the best all round effects were obtained with farmyard manure of physiologically acid fertilisers like ammonium sulphate.

Tallarico (1932 carried out experiments which showed that natural manures showed specific effect not exerted by artificial fertilisers, and generally that seeds from plants that are over-nourished during the growth period have less vitality than seeds from a poorer soil.

Thompson (1937) has drawn attention to the influence of fertiliser treatment and time of ripening on the germination of lettuce seed.

Pfaff and Roth (Biochem. z 297 ; 137, 1938) report that barley grains with a high nitrogen and vitamin B content have a higher rate of germination than those with a low content, and that young plants grown from the former are superior in growth ability as well as in chlorophyll and vitamin content.

Beuchamp and Lazo (1939), discussing the relation between vigour of seed and nutritive elements in sugarcane setts, have stated that, in the case of two months ratoon cane shoots, the vigour of the "seed" appeared to depend on reserve nutrients.

Nehring (1939), in his investigations on nitrogen supply on the protein contents of barley varieties, has observed that differences in the seed caused by varied fertilisation of the plants producing the seed, were evident in differences in the volume weight of the second crop with uniform treatment.

Albert, *et al.* (1939) report results of experiments in which they compared the seed value of potatoes grown on sandy loam and peat respectively. Trials for four years in 1934, 1935, 1936 and 1937 showed that seed raised on peat soils grew more vigorous plants and gave significantly increased yields than the seed raised on sandy loam.

Viswa Nath and Suryanarayana (1927) explained the variation in seed vigour with manuring as being due to the variation in the seeds of certain substances similar to auximones and vitamins which are passed on to the seed by the mother plants. Cholodney (1939) in a review on the internal factors of flowering has cited the investigations of several workers between the years 1934 and 1938, and observed that the seed reserves of phytohormones received from the mother plant are concentrated chiefly in the endosperm or cotyledons, and that this reserve comes to action during germination and is transmitted to the organs of the embryo beginning growth and development.

6—The Influence of Plant Nutrition on the Composition and Nutritive Value of the Crop

McCarrison and Viswa Nath (1926) have shown that manurial and fertiliser applications are capable of reacting on plants in a manner as to change their composition and nutritive value. They have shown by animal experiments that produce raised on a poor soil and with no fertilisers is poor in nutritive value, and that produce raised with mineral fertilisers on soils poor in organic manure is, in turn, inferior to the produce raised with farmyard manure or cattle manure. These authors carried out experiments with the millet (*Eleusine coracana*) and wheat grown on the permanent manurial plots at Coimbatore. Later experiments by Viswa Nath with the grain of *Andropogon Sorghum* and other herbage at Coimbatore and with wheat (Pusa 52) gave similar results, but an experiment with *Pennisetum typhoideum* was an exception and did not show differential nutritional response with different manurial treatment.

Hunt (1927) in the U. S. A. concluded that acid phosphate produced wheat with high vitamin B content.

Roalands and Wilkinson (1930) of the Knightsbridge Laboratories, London, carried out nutritional and curative experiments, and have recorded that grass seeds from the plot manured with cattle manure had a better nutritive and curative value than the seed from a plot fertilised with mineral fertilisers.

Tallarico (1932) in Italy carried out experiments in which turkeys were fed with grains raised on land fertilised with cattle manure as well as grains from land treated with mineral fertlisers. The former showed more resistance to disease than the latter, and those that contracted disease were less seriously affected, recovery was more rapid and the proportion of fatal cases was less.

Johnson (1933) and Potter (1933) in the U. S. A. observed that 60 per cent of the animals receiving Vinesap apples from trees to which fertilisers were applied were either protected or developed only mild scurvy, while among animals fed from trees with no fertiliser treatment, not one was protected and 80 per cent of the animals developed moderate to very severe scurvy.

Hahn and Gorbing (1933) have noted variation in the vitamin C content of spinach with the nature of manuring. They observe that not only unsuitable manuring but any departure from normal conditions of growth tends to diminish the vitamin content.

Scheunert and associates (1934) in Germany investigated the question of the continued use of commercial fertilisers, and compared crops raised with mineral fertilisers with those raised without fertilisers. They concluded that food-stuffs grown with heavy and continued applications of mineral fertilisers prolonged the life period of animals and improved their reproductive capacity as compared with similar foods grown without mineral fertilisers. He presumably did not carry out comparative experiments with produce grown with organic manures.

Harris (1934) in England carried out experiments at the Nutritional Laboratory at Cambridge with samples of wheats grown on differently manured plots at the Rothamsted Experiment Station. He carried out his tests for Vitamin B_1 by the Bradicardia or heart rate method, using, after preliminary tests, 2 grams doses of the wheats from the differently manured plots. The experiments lasted for eight days. The relative vitamim B_1 activities of the wheats were :—

Plot	*Manurial treatment*	*Vitamin B activity*
2B	14 tons of dung; No manure	... 100
5	Complete mineral manure + 412 lbs. sulphate of ammonia per acre	... 80
7	Complete mineral manure + 412 lbs. sulphate of ammonia per acre	... 120
10	412 lbs. sulphate of ammonia only per acre	

Experiments were next carried out by the growth rate method with "sharps" prepared from wheats from the four differently manured plots, using each sample at

four levels at $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$ and 1 gm. per day. The feeding was continued for twenty days. The growth rate of animals varied with the dose of wheat 'sharps' given. Harris concluded that no notable variations due to manurial treatment existed. In the case of $\frac{1}{4}$ gm. dose, the increase in body weight of the animals, as judged by the growth curves, was greatest in the case of animals receiving wheat from the plots manured with dung. Numerical data are not available, but as deduced from the curves the approximate increases in body weight over that of the initial are :—

Plot	*Manurial treatment*	*Increase in body weight over the initial in gm.*
2B	14 tons dung	... 22
3	No manure	... 16
5	Complete mineral manure + 412 lbs. sulphate of ammonia per acre	... 9
10	412 lbs. of sulphate of ammonia only	... 15

It is interesting that the trend of the results due to treatments was similar to those obtained by McCarrison. Possibly the other doses were either too small or too large for the tests.

Ranganathan (1935) of the Nutrition Research Laboratories, Coonoor, in an investigation of the vitamin C content of Indian food-stuffs, reported that specimens of spinach obtained at the same time from two different gardens, one well manured with farmyard manure and the other poorly manured, gave significantly different values. The value for the well manured spinach was 63·7 mgm. per cent., while that for the poorly manured spinach was 36·9 mgm. per cent.

Ijdo (1935) found correlation between the nitrogen and potash content of the soil and vitamin C content of spinach. A large amount of nitrogen results in a larger carotene and vitamin C content of the leaves, while a large quantity of potassium lowers the carotene content and raises the vitamin C content.

Fürst (1936) reporting Lieber's results stated that, compared to unmanured plots, the effect of complete manuring of grasses with mineral fertilisers was a significant increase in the vitamin A content, where as the vitamin B_1 content was hardly affected.

Scheunert and Schieblich (1936) tested three samples of wheat raised with (1) manure, (2) mineral fertilisers and (3) a mixture of manure and mineral fertilisers. One gramme of wheat by the manure alone contained 1·2 international units of vitamin B_1 and the other two 1·5 units each. The same author found that samples of hay from potash manured plots did not differ in their vitamin A, B_1 and B_2 contents compared to samples of hay from unmanured plots. Investigating the vitamin B_2 content of potatoes, Scheunert and Wagner (1938) considered that the slight

variations in the vitamin content of potatoes grown with and without mineral fertilisers could not be attributed to their specific effects.

An extensive series of nutritional experiments by several workers with vegetables grown in Germany with different manures are reported in 1938. These experiments were carried out in 1936-37 under the joint auspices of the Association for Scientific Research, the National Board of Health and the Society for Nutrition Research. The nutritive value of vegetables grown with animal manure plus mineral fertilisers was compared with that grown with animal manure. Fifteen kinds of vegetables were grown on experimental plots for the State Institute for Teaching and Experimental Reasearch in Weihenstephan. On adults the results showed no definite effects On children the results showed that vegetables grown with animal manure plus mineral fertilisers were superior to those grown with animal manure only.

Ott (1937) has reported results of experiments with potato. He found that full chemical fertiliser treatment gave the same vitamin C content as the control plot to which no chemical fertiliser was applied. If part of the fertiliser consisted of organic manure greater content of vitamin C was obtained than with exclusive use of complete chemical fertiliser. The formation of carotene was influenced much more than that of vitamin C, by the type of fertiliser treatment.

Isgur and Fellers (1937) observe that vitamin C increased in general with fertiliser treatment in Swiss "chard" but not in New Zealand spinach.

At the Massachusetts Experiment Station (1938) the effect of nitrogenous chemical fertiliser on the ascorbic acid (vitamin C) content of tomato was tested. In twelve strains those receiving high nitrogen contained ascorbic acid ranging from 74—114 units per ounce of tomato, while those receiving low nitrogen ranged from 96—136 units.

Wachholder and Nehring (1938) carried out experiments with potato and concluded that, in general, the vitamin C value for tubers manured with farmyard manure was greater and less affected by cooking than those for tubers grown with mineral fertilisers only.

Kühl (1938) reported that Schrœder's attempts to raise the vitamin B content of plants by manuring gave inconclusive results

Schuenert and Wagner (1939) carried out experiments with barley, carrot and other vegetables on the influence of mineral fertilisers on the vitamin contents. Experiments with barley showed no relationship between the vitamin content of B_1 and B_2 and the manner of fertilising. The vitamin A content of carrots was fairly uniform at 100 international units per gramme of fresh carrot quite independently of the nature of fertiliser treatment. In regard to vitamin A in green cabbage, spinach, Brussels sprouts and tomatoes, Scheunert and Wagner state

that, except under conditions of extreme lack of nourishment, the vitamin A content of plant tissues is not materially affected.

Leong (1939) tested on the lines of Harris in 1934 (loc. cit) the vitamin B_1 content of wheat and barley raised on differently manured plots at Rothamsted and harvested in 1935 and 1936.

International unit vitamin B_1 per gm.

Treatment	*Wheat*	*Barley 1935*	*Barley 1936*
14 tons dung per acre ...	1·2	2·0	1·1
No manure	1·0	1·1	0·8
Complete mineral manure ...	1·3	1·3	0·8

Leong's conclusions were that the vitamin B_1 potency of wheat and barley was not influenced by manurial treatment.

Ysabel Daldy (1940) has reported Chapman's results on feeding school children in New Zealand. From three years of tests, Chapman found that, judging from the growth and health of school children, the feeding of vegetables grown with organic manures was markedly superior to that of those grown with mineral fertilisers.

Booth (1940) of the Research Association of British Flour Millers, in England, and Schweitzer and Dalby (1940) of the Ward Baking Company in U. S. A., tested a large number of wheats and whole wheat flours for their vitamin B_1 (aneurin or thiamin) contents and found considerable variations in vitamin B_1 content due to variety and locality. Booth's data also provide information on the aneurin content of wheats grown under different systems of cultivation and manuring in England.

Variety	*Manuring*	*Aneurin content i u per g.*	*% difference over normal*
Yeoman II	Normal	1·22	...
Do.	Intensive	1·27	+ 4·1
Do.	Fenland	1·81	+50·4
202 (47 B)	Normal	1·04	...
Do.	Intensive	1·17	+ 12·5
Do	Fenland	1·80	+73·1
Despre Z 80 (Jonequois)	Normal	1·02	...
Do.	Intensive	1·33	+30·4
Do.	Fenland	1·54	+51·0
Squareheads Master	Normal	1·43	...
Do.	Intensive	0·78	−90·6
Do.	Fenland	1·33	− 7·5
The Warden	Normal	1·25	...
Do.	Intensive	1·43	...

The above are English wheats, *Triticum vulgare* sp. of the National Institute of Agricultural Botany, 1939 harvest. Booth has observed that manuring of wheat causes no uniform or predictable alteration in vitamin B_1 content, but that it is significant that the intensity of manuring and particularly fenland (high farming) samples are higher in vitamin B_1 content.

The results reviewed are in agreement with those of McCarrison and Viswa Nath in two respects: that is, a manured crop showed higher nutritive value than an unmanured crop, and a mixture of organic manure and mineral fertiliser was better than either of the two. In regard to the relative merits of the produce raised with organic manures and mineral fertilisers, the evidence is conflicting. That is probably due to the differences in the organic matter content of the soils. Where the soils are already rich in active organic matter, it is to be expected that further additions of organic manure will have no effect, and in that case mineral manures will be effective. Where the organic matter is low and the soils are of a mineralised nature, the addition of organic manure will be followed by general improvement. McCarrison's animal experiments lasted for periods of 70 and 90 days, while those of Harris and of Leong did not last for more than 20 days and the test was for vitamin B_1 only, and even so the trend in favour of organic manure is distinct. Differences in nutritive values of food crops due to manuring cannot be ascribed to one particular factor. It is the result of the combined and cumulative effect of several including long time effects.

7—The Influence of Nutrition on the Protein Complex and its Biological Value

McCarrison and Viswa Nath (1926) in their first report attributed the variations in the nutritive values of crops raised with different manures, to the differences in their vitamin contents. Subsequently Viswa Nath (1932) suggested that the superior nutritive effects of the produce raised with organic manure might be due either to the relatively high vitamin contents of produce or in the synthesis of the important food constituents of the produce such as proteins. In experiments with the herbage of *Eleusine coracana* 1930-31 the coefficient of digestibility varied with the nature of manuring. Herbage raised with cattle manure had a digestion coefficient of 74 per cent, while the digestion coefficients of herbage raised with mineral manure and without manure were 70 per cent and 62 per cent respectively, when the test animals were fed on equivalent protein basis, and besides the herbage raised with cattle manure contained the lowest amount of nitrogen and soluble ash content compared to the other two samples.

This observation led to an investigation of the protein complex in the crops raised with different fertiliser treatments. The ordinary methods employed in the

analysis of feeding-stuffs not being adequate for the study of the nitrogen compounds occurring in plants, fractionation by different solvents was employed to arrive at the quantities of the empirical protein fractions.

Ramaswamy, working with Viswa Nath (1933), noted that the total extractable protein and the proportions of the so-called albumins, globulins and prolamins in the millet *Pennisetum typhoideum* varied with the nature of manuring.

PROTEIN EXTRACTABILITY

Manurial treatment	*Percentage of the total protein extracted by various solvents*
Grain raised without manure	85·00
Grain raised with mineral manure	91·86
Grain raised with cattle manure	96·97

Later Satyanarayana, working with Viswa Nath (1937-38), found similar variations in the digestibility, biological value and the nett protein value of wheat (Pusa 52) raised under different systems of manuring.

Schmalfuss (1932), investigating the protein metabolism of plants, has observed that high nitrogen contents in plants, resulting from excess of nitrogen supply either directly or through a deficiency in the availability of other constituents, is due to an increased proportion of soluble nitrogen rather than to protein nitrogen.

Crampton (1934, 1935), from investigations on the nutritive values of manured and unmanured pastures, considers that the effect of manuring pastures is to alter the nature of the protein complex of herbage in particular species as well as to change the botanical composition.

Potel (1936) has observed that, although the nitrogen content of wheat grain remains constant in composition, the proteins vary considerably, largely by modifications in the hydration capacities.

Rautenberg (1938) carried out analyses on plants, in which differences in the content of nitrogen compounds had been induced by different manurial treatments. The results of his investigations show that plants which do not differ from one another in respect to their contents of the different protein fractions, may exhibit considerable differences when the compounds which go to build up the proteins and the non-protein nitrogenous bodies come to be considered.

Iyengar (1939), working in Viswa Nath's laboratory, analysed wheats (Pusa 52, 1938 crop) raised with different manures for their different protein fractions and constituent amino-acids, and found that while wheat raised with cattle manure did not show appreciable variations, that raised with green manure showed significant difference in composition compared to that of wheats raised without manure and with mineral manure.

Bercks (1939) examined, for proteins and other constituents, the mature grains of barley and oats raised in pots under different levels of different fertiliser applications. Nitrogen increased absolutely with its increased application to the soil, but the accumulation of the excess nitrogen was as amides.

Baumeister (1939) from experiments with wheat came to similar conclusions as those of Bercks. An interesting observation of Baumeister is that in instances where fertilisers were not in excess and were as nearly balanced as possible, there was an increase in the thickness of aleurone layers in which the vitamins and auxins reside

Ramiah (1938), in investigations on rice grown under different manurial treatments, has recorded that organic manures thickened the aleurone layers of grain significantly more than was the case with mineral fertilisers.

Ramiah (1939) reports that the effect of ammonium sulphate on the herbage or cereal crops is that while it increased the nitrogen content in the plant, the greater part of the nitrogen remained in the form of nitrates and was of little value as food.

8—Accessory Nutritional Factors for Plants and the Cycle of Accessory Factors in Nature

The plant experiments on seed quality and vigour by Viswa Nath and Suryanarayana and the animal nutrition experiments by McCarrison discussed in the previous sections were carried out with the same materials. That is, the same grain that was used to test seed quality or vigour was used by McCarrison in his nutrition experiments. The grain from cattle manured crop which showed greater vigour and grew better plant also possessed better nutritive value and higher vitamin content than the grain from the mineral manured or unmanured crop. The grain raised with organic manure was evidently richer in some constituent that stimulated plant growth and was also richer in vitamin. It appeared that the plant growth stimulant and vitamin might be either the same or inter-related or might be a precursor to vitamin formation.

Acting on this line of thought and in the light of previous experiments of Bottomley, Viswa Nath and Suryanarayana (1927) carried out plant experiments with fractionated extracts of farmyard manure, composts and yeasts, and found that the active constituents in the extracts of manures and micro-organisms were absorbed by the plants and that their metabolism was stimulated. From these and other experimental results Viswa Nath and Suryanarayana (1927) postulated that in their fundamentals the subtle physiological mechanism in plants is similar to that in animals, and that both require accessory food factors, akin to vitamins, for growth, development and health In their memoir (1927) Viswa Nath and Suryanarayana

submitted evidence and arguments to show that (1) organic manures, besides improving the physical condition of the soil and being sources of the ordinary food constituents for plants, also supply some agents like auximones or vitamins which contribute greatly to the growth and reproduction of plants; (2) in addition to their bio-chemical activity, the micro-biological population of the soil contribute directly to the plant some stimulant which is ultimately passed on to the animal; and (3) auximones for plants and vitamins for animals are probably the same or if different exist together and are independent, functioning in different ways according to the organism in which they are introduced and the conditions under which they operate.

In a later communication Viswa Nath (1932) observed that the response to vitamins and the capacity to synthesise thus appears to be universal from the simplest unicellular organism to the most complex multicellular animals, and that it is reasonable to state that plants normally require auximones or vitamins, and if they can get them readily available they will utilise them and that otherwise they exercise their powers of synthesis.

Several other workers subsequently obtained results more or less similar to those of Viswa Nath. But the most authoritative confirmation comes from the discussions on the subject by the Royal Society, London. The society held a discussion led by Kögl (1937) on "growth factors." In reporting the conclusions reached at the discussion, *Nature* (1937) observed that the case established in the nutrition of animals is equally well established in the nutrition of the most diverse varieties of cells; namely, that all cells from the lowliest bacterium to the cells of the highest animals are enabled to carry out the series of reactions by the agency of substances mostly of a nature akin to vitamins in animal metabolism.

A remarkable development that has given further support to these findings is that of phytohormones or auxins. The action of these substances in the plant is similar to that of vitamins in the animal body. When adequate supplies of food and water are assured for plants, minute quantities of these substances have been shown to bring about results out of all proportion to their quantity. In animal physiology and animal chemistry the test animals for the study of vitamins and animal hormones in the laboratory are rats, rabbits and guinea-pigs. In plant physiology the test objects are the coleoptiles, the ends of shoots of young seedlings or whole seedlings of lower and higher orders of plants and micro-organisms.

Kögl and his associates (1933-34) isolated auxins which are also known by the name of growth substances, growth hormones or phytohormones, and also studied their chemistry and constitution. At present three auxins have been demonstrated as naturally occurring in plants. They are organic substances, auxin (a) and auxin (b) and hetero-auxin. The first two are acids but possess different chemical structures. The third, hetero-auxin, is identical with B-indolyl acetic acid. Auxin (a)

is stable in the presence of acid and is sensitive to alkali. Hetero-auxin is stable in the presence of alkali and sensitive to acid, while auxin (b) is disabled by acids and alkalis.

Originally the experimental source of auxins was human urine which contained about 80 per cent of auxin (a) and 20 per cent hetero-auxin. Auxins have been shown to occur also in numerous plants, plant parts, and plant products. Hetero-auxin which is B-indolyl acetic acid is constitutionally unrelated to the auxins (a) and (b) and is present in cattle manure and other organic manures. They have also been found in several fungi and bacteria Boysen-Jensen (1936), in his review on growth hormones in plants, has observed that there is some indication that the plant growth hormones found in animals have their origin in the materials supplied in plant food.

Since the isolation of the auxins and the study of their chemistry several hundreds of paper have been published dealing with various aspects of their part in plant growth and development. The auxins or phytohormones have been shown to play a definite role in many life processes of plant. They have been shown to be concerned with the germination of the seed and the growth of the seedling plant. They have been demonstrated to play an essential part in the growth of higher plants regulating cell division and elongation. These investigations have provided the means for demonstrable and valid explanations for plant behaviour.

Rasnizina (1938 determined the amount of auxins formed by various soil bacteria and noted varying degrees of ability for auxin production. While certain organisms did not produce auxin, certain others produced large quantities.

Roberts and Roberts (1939) investigated auxin production by the micro-organisms in Indiana soils. One hundred and fifty species of actinomycetes, bacteria and molds were tested for their capacity to produce auxins in organic and synthetic inorganic medium. Sixty per cent of the species produced auxins on the organic medium, while thirty per cent produced on the inorganic synthetic medium.

Hitchcock and Zimmerman (1935) reported results of experiments in which they state that plants absorb synthetic growth substances from the soil as they do mineral elements through roots, and that this absorption is influenced by the transpiration rate which also influences rate of movement in aerial parts when growth substances are introduced as water solutions in the transpiration stream. Following their entry and upward passage into the different parts of the plant, their effects upon growth, root formation and other developments are very striking. These observations appear to contradict the previous conclusions as to the polar movement of growth substances, and commenting on these results Boysen-Jensen (1936) have observed that as the upward migration was greater than 47 c.m. per hour under optimum conditions, it is probable that translocation of the substances in this instance was in the inspiration stream. The dead cells of the xylem are doubtless the path ways of transport;

hence the observation does not contradict the evidence for polar movement through living tissues.

Loehwing (1936) studied plant growth effects of heteroauxin applied to soil and plants, and observed significant effects when put on plant but not as clearly as when put on soil and absorbed.

Greenfield (1937) investigated response of stock seedlings to heteroauxin applied to the soil in pot cultures. Applications upto 3·0 mgm did not affect growth rate; 6·0 to 12·0 mgm caused accelerated growth; significant inhibition was produced by doses of 48·0 or 96·0 mgm per pot and caused bending of the stems near the base, but after three days the stems became straight.

McRostie *et al* (1938) investigated the effect of dusting phytohormones on growth and yield of winter wheat. Differences between the hormone treated and untreated sub-plots in respect of early growth and subsequently density of stand were apparent on visual inspection. There were also statistically significant differences in respect of straw production, yield, weight per bushel and nitrogen content of grain.

Amlong, H.W. and Nanndorf (1938) report studies on the effect of growth stimulant treatments on agricultural and horticultural plants, and observed distinct but varied effects with sugar beet, artimisia, cucumber, daphne and winter endive.

Templeman (1939) reports no effects in sand cultures of hetero-auxin with a restricted and ample supply of nitrogen, either by spraying on foliage, watering on to the sand or steeping the seed in solution.

Kögl (1938) in the course of a discussion on growth factors has suggested the existence of a cycle of growth substances in nature. He has illustrated the suggestion by an experiment in which neither *Polyporous adustus* nor *Nemotospora gossypii* is able to grow in a synthetic medium; when inoculated together they develop. He considers that apparently *Polyporus* supplies biotin (of yeast), whilst *Nemotospora* furnishes aneurin (vitamin B_1).

According to Bonner (1937) and Robbins (1937), aneurin (vitamin B_1) functions as a hormone of root growth. These workers find that, under normal conditions, the extremely small amounts of aneurin required for root growth are supplied by other parts of the plant. Without aneurin or its derivatives no root development is possible. This is suggestive that aneurin is the limiting factor for root development on cuttings. The work of Went and associates (1938) provides support to this view in demonstrating that if aneurin is made available at the proper time root development is greatly increased in cuttings. Kögl (1938) observes that we are induced to realise that aneurin (vitamin B_1) which is of such essential importance for the normal proceeding of the chemical processes inside the nerves, is also of physiological importance for the rice grain itself. Ramiah (1938) has observed thicker aleurone layer in rice grains grown with organic manures.

The work of Thimman (1934) and the more recent work of Link (1937) and of Link and associates (1937) indicates the rôle of micro-organisms as contributing factors for stimulating and regulating plant processes. Hetero-auxin has been identified as a constituent of ether extracts of cultures of *Rhizobium Phaseoli* (legume nodule forming organism). Link (1937) in a later communication to *Nature* brings forward evidence and has suggested that the beneficial effects of green-manuring, dung, urine, compost and humus soils to be due to the hetero-auxin they contain.

The question of the production of auxins or plant hormones by mineral nutrition was studied by Avery and associates (1936). They employed the common sunflower plant and the tobacco plant, using sand cultures of mineral salt solutions of different compositions and strengths. The results showed considerable differences in auxin production. The smallest amount of auxin production and the least growth occurred in the absence of nitrogen. Increased vigour and greater amounts of auxin were found in plants receiving nitrogen, but the response was not proportional to the increase in nitrogen contents. Increase of nitrogen beyond a certain limit reduced auxin content. In field experimental fertilised plots, auxin production was unaffected by the relative deficiencies of common elements in the fertiliser salts used.

The same authors in another communication (1937) have reported the results of further experiments. The concentration of auxins in sunflower and tobacco varied directly with the growth vigour and nitrogen concentration. Deficiency of sulphur, phosphorus, potassium and magnesium had no effect on the quantity of growth hormone produced, but lack of calcium decreased the concentration.

These results when read with the investigations of Schmitz (1933), Cholodny (1935), Laibach and Meyer (1935) and Pohl (1935), who have demonstrated the presence of auxin or growth hormone in the endosperms of seeds, provide further evidence how manuring can influence the quality or vigour of the seed material. These authors have shown that the auxins received from the mother plant are passed on mainly to the endosperms or cotyledons. Pohl's experiments show a decrease of as much as 25% if the seed coat and aleurone layer are removed or punctured so as to allow the outward diffusion of the auxin from the endosperm. Auxin added to the seeds whose auxin supply had been removed caused normal growth in length of the coleoptiles. It has already been mentioned in a previous section that organic manures contain auxins and that they are absorbed by the plant and transported upwards.

There remains the question of the effect of vitamins on plants. Bonner (1937) has reviewed the rôle of vitamins in plant development. The available evidence shows that all the vitamins function as accessory factors for plants. More recently Robbins (1939) discussed the position of thiamin (vitamin B_1) with regard to plant growth, its functions and its specificity. He states that thiamin is needed in small

amounts for the normal development of a living organism (which term includes micro-organisms, higher plants, animals and human beings), and that depending on the organism concerned thiamin may be considered to be a vitamin, a hormone or as something which is neither a hormone nor a vitamin. He is further of the view that thiamin (vitamin B_1) is necessary for the growth of all or nearly all organisms; that some are capable of making the thiamin they require; that some must be supplied, while some fall between the two extremes with varying degrees of synthetic power. In a previous section we have seen how manuring influences the vitamin B_1 content of crop plants. In some of them the increase due to manuring ranged from 4 per cent to over 70 per cent, while in others there was even nearly 90% decrease. In this connection the following figures given by Bonner and Green (1938) for vitamin B_1 contents of manures and other materials, and by Rasnizina (1938) for auxin values for soil micro-organisms, are interesting and significant.

Vitamin B_1 content of manures and other material

	Vitamin B_1 content on air dry substance mgm. kilo.
Arizona steer manure	0·13
Local steer manure	0·08
Cattle manure (cows)	0·13
Alfalfa plant	5·00
Azotobacter (grown on synthetic medium)	140·00

Auxin content of soil micro-organisms

	Auxin content in terms of max curvature
Mycobact rubrum, B. mycoides, Rhizobium leguminosarum	0·0 to 11·0
B. Subtlis	19·4
Azotobacter vinelandii	4·2
Azotobacter agile	8·2
Azotobacter chroococum (strain A)	26·8
" " (" B)	28·2
Psendomonas fluorescens	26·8
Mycobacterium album	29·8

9. Newer Knowledge of Plant Nutrition

The necessarily brief and rapid survey of scientific research in the intermediate field between agriculture on the one hand and nutrition and health on the other, has revealed the trend of modern thought and research. It has brought to light

new knowledge on the relationship in the life processes of plants and animals (including human beings) necessitating a fresh outlook on, and a new orientation to, the problems of soil, plant and animal research.

The recent developments provide logical and demonstrable evidence in support of the statement made fifteen years ago that plants like animals need and respond to accessory factors, and that the rôle of organic matter and organic manures, particularly farmyard manure, is, besides exercising a direct influence on plant nutrition and metabolism, to help in the maintenance of the accessory food factor cycle in the co-operative existence of plants and animals. The cycle or chain starts with the organic matter and micro-organisms in the soil and passing through the plant reaches the other end, namely, animals and human beings, finally going back to the soil only to go again another round in the cycle.

One of the most interesting features about these discoveries is that they reveal continuity and unity in the apparently diverse discontinuous life processes in nature, and remind afresh the kinship in the organic world as revealed by the fact that the minute and humble yeast cell requires for its proper nutrition the same substances as the high and mighty plants, animals and human beings. It is indeed interesting that the forecast made by Viswa Nath (1933) that the knowledge would one day enable consideration of plant in terms of animal in certain respects, and that on that basis it might be possible to use plant as a test organism in the study of certain problems connected with animal life as in nutritional and other studies, has come to pass and is now one of the methods for the investigation of hormones and vitamins.

Modern research has shown that in their essentials the bio-chemistry of plants and animals is similar. Both respire; both require food and in both the processes of digestion and assimilation of food and growth and well-being are guided and controlled by enzymes, hormones and vitamins and minerals of a similar nature. Both have sexes and both reproduce. In both the vigour and health of the offspring depend on the nutrition of the mother organism, and in both plants and animals adequate and correct feeding of the infant leads to the development of a healthy and robust adult. Both are not happy on artificial nutrients for a long time and both require accessory food factors.

But what about excretion by plants? Until recently it was thought that plants like animals do not excrete, and this is explained on the basis that plants are less likely to have accumulation of waste as plants are supposed to be relatively less energetic. The existence in plants of such nitrogenous substances as urea, asparagine, glutamine, allantoin indicates that plants do have degradation products of protein metabolism, and the occurrence in plants of corresponding enzymes like ureas is an indication that plants have a special mechanism for dealing with physiological waste products in a more economical way than the animal does. Pryanishnikov (1928) studied peas, beans and oats from the point of view of ammonia excretion, and his

results show that the plants respond to acid excess in the same manner as the animal organism does, by increased ammonia excretion, the latter being directly related to the protein content of the plant. This alteration in the metabolism of plant with the production of ammonia has been observed not only in poisoning with acid but also with physiologically acid salts like ammonium chloride and ammonium sulphate, fasting or unbalanced nutrition by way of excessive nitrogen supply.

Although a considerable amount of work has been done on the absorption, assimilation and metabolism of the mineral elements of nutrition by plants, text-books on plant physiology do not state what ultimately happens to the absorbed salts. It has been tacitly assumed that they are retained in the various plant organs. Over thirty-five years ago, Wilfarth, Romer and Wimmer (1906), in the course of their investigation on the assimilation of the elements of nutrition by wheat and barley during different periods of their growth, observed that the amount of mineral nutrients absorbed did not remain in the plant and that a part of it returned to the soil with the possible exception of phosphorus. Burd (1919) in a similar investigation observed a similar flow back of minerals from plant to the soil. Viswa Nath (1932) has shown from soil solution studies that a downward migration of salts occurs from the plant into the soil after the plant has completed its elaboration of the absorbed materials into the final products of storage. Penston (1935) summarising the results of several Rumanian workers found in the later stages of development a considerable return of mineral elements including nitrogen from plant to the soil. Loehwing (1937, 1940), in a review on root interactions of plants and on mineral nutrition in relation to flower development, has reported on the excretion of various organic substances including amino acids and vitamins. The absorption of water and nutrients during the growing and development period, and in their subsequent assimilation period during which carbo-hydrates and proteins accumulate, is suddenly checked at the flowering period, from which begins a rapid negative translocation of mineral salts and organic substances, a portion of which returns to the soil. This phenomenon of nutrient excretion is, according to Loehwing, is especially evident in plants grown at high nutrient levels.

This knowledge on the migration of minerals and nutrients from the plant into the soil is helpful in laying the foundations for the clearer understanding of the soil plant relationships; particularly on the effect of certain crop rotations on soil. Incidentally it throws doubts on the validity of estimating by plant analysis, the drain on the soil's mineral resources by crops, and on the utility of estimating fertiliser requirements by soil analysis either by rapid or slow methods.

The science of plant and crop nutrition has made rapid strides in recent years and has thrown further light on the greatest problem of all times, namely, that of producing food for men and animals. In its wild state the growth and development of plant is governed by that inexhorable law of nature by which only the fittest can

survive. The plant then flourishes in its natural environment and the quality and the quantity of the plant and its products will then be typical of its kind. With the interference of man, and the coming of the plant under the regime of cultivation, the natural balance is upset, and it then becomes necessary to carefully minister to the needs of the plant. An instructive example is afforded by the organism yeast. Wildiers (1901) observed that yeast when inoculated into a medium containing inorganic salts and sugars did not grow and bring about fermentation until a substance which he called *bios* was made available in the culture. This observation could not always be verified by other workers until Copping (1929) showed that only yeasts which were highly cultivated needed the addition of *bios* for their development on artificial media, and that wild yeasts did not require the growth factor. This observation of Copping is significant in the case of the highly cultivated plants in agriculture. The nutrition or manuring must be such as to meet their requirements. The rice plant is another instructive example. Kennedy (1924) has shown that wild rice possessed better nutritive value than cultivated rice. Man's aim in crop production should be to simulate nature as far as possible by rational soil treatment and crop nutrition.

The newer knowledge has opened fresh fields for fruitful study. Each revelation may appear to lead to greater and greater complexity but in reality is moving towards greater unification arising from a better understanding of the diverse factors. Already we see the beginnings of a new field of agricultural or biological research. The unity in the essential principles underlying the bio-chemical mechanism of all life calls for attack over a wide front in the study of kindred phenomena. The importance of the study of plant nutrition and metabolism in relation to the problems in animal and human nutrition, and the knowledge of the existence of variables and even contradictions, are the greatest stimulus for the study of the phenomenon, keeping in view even apparently little related facts.

10. The Bearing of the Newer Knowledge on Practical Problems in Agriculture and Nutrition

Agricultural scientists are engaged in breeding crops for high yields and with acknowledged success. Is it possible to combine high yield with high protein content? There is no definite evidence on this point but what little there is, points in the negative direction. The relationship between yield and protein content of wheat and rice crops evolved at the Imperial Agricultural Research Institute and at Coimbatore has been under study. The available results have not given clear indications. Vitamin B_1 index of the grain does not appear to bear any relationship to protein, but there are distinct indications of relationship with yield.

Ludecke (1936) at the Agricultural Experiment Station in Bernburg obtained in pot culture experiments with barley and with varying intensities of potash

manuring results in which the protein content of grain decreased with increase in yield, as will be seen from the following figures :

Yield of grain in gm.	Protein content of grain %
1·41	24·01
2·28	22·31
3·39	19·92
12·63	13·70
19·03	11·86

If this is also the case in the field, the yield of protein per acre goes high but the protein content in the grain as a component of diet will be less.

Wilcox (1938) has shown that in sugarcane and sugar beet high yield and low nitrogen content go together. Jose Carreras (1938), confirming Wilcox's observations with regard to sugarcane, observes that in Peruvian wheats yield is inversely proportional to the nitrogen content of the wheats. Ivonov (1935) holds that combination of yield and high protein by selection and breeding is more difficult with cereals than with leguminous crops like peas and lentils, but considers that with gram (*Cicer arietinum*) the difficulty will be as great as with cereals. In Canada, Neatby and McCalla (1938) have shown that high-yielding varieties of wheat and barley have a marked tendency to be constitutionally low in their protein content. These workers consider that while varieties characterised by moderately high yield and high protein content are known, it is doubtful whether in plant breeding the maximum possible yield can be combined with maximum possible protein Isenbeck (1938) reviewed the question of the possibility of combining high yield and protein quality in wheat, and stated that the combination has yet to be obtained.

Russell (1939), reviewing the results of Rothamsted field experiments on barley during a period of seventy-five years, has stated that a negative correlation is observed between the nitrogen percentage in the grain and yields.

The desired combination of high yield and high protein content has, therefore, to be secured by manuring. If that is the alternative, should a variety be bred for its high protein and then endeavour made to increase crop yield by appropriate manuring, or should the protein content of a high-yielding variety be raised by appropriate manuring? We have no data to answer these questions. We have so far concentrated our attention on quantity and have not bestowed attention on quality. Seeing that what little evidence is available, points to inverse relationship between nitrogen and yield, the possibility of increase by manuring may be examined.

Although manuring is seen to alter the composition of the plant, it may be possible to so control manuring as to increase yield with the least interference with protein or other qualities. The early part of a plant's life is characterised by a

greedy absorption of nutrients from the soil and using them in the building-up of the necessary structure and the complex products like protoplasm, complex carbohydrates and proteins. In the later period of the plant's life what may be called the re-elaboration of the absorbed material takes place. It does not mean that only the processes of one phase are carried on at a time and that the others cease. It means only that one set of physiological and biochemical reactions predominates at a given phase according to the life-period of the plant Initial and inherent differences due to variety may affect the length of the early period without necessarily and proportionately influencing the length of the later periods of elaboration and maturity, but whatever conditions operate in the early period, they can influence the reactions in the later period. In the end, the organic and mineral composition of the crop depends on the conditions available. It would, therefore, appear simpler and more possible to increase the crop yield of a high-protein variety with low-yielding quality by suitable manuring than to increase the protein content of a high-yielding variety with a low protein content.

The growing knowledge on the effect of manures and fertilisers on plant metabolism and on the quality of plant products and the new interpretation of the rôle of organic matter in plant nutrition is of interest in the study and the solution of the related problems of agriculture and national nutrition. The problem of nutrition is essentially the development and maintenance of what may be called "biologic balance" in crop and animal husbandry.

The significance of this knowledge will be evident when it is realised that large cultivated areas of the country are poor in organic matter and other plant nutrients, and that very large sections of people depend on the food (animal or vegetable) raised in these areas. This means dietary defects resulting from a low level of intake of certain foods which are also deficient in certain essential constituents, because they are raised on deficient soils. Under such conditions the chances of physiological disturbances and reduced vitality are increased, and even if disease may not manifest itself in a pronounced manner, there can be different degrees of health and lowered vitality and impaired efficiency.

A recent review (1940), by Russell and associates, of the comparative manurial experiments with wheat for 97 years at the Rothamsted Experiment Station with mineral fertilisers and with farmyard manure, has led to the following conclusions:—

1. Average yields are approximately the same in both.
2. Seasonal fluctuations in yield are smaller on the farmyard manure plots than on mineral fertiliser plots.
3. Deterioration of yield with time is slightly lower in farmyard manure plots than in mineral fertiliser plots.
4. No significant differences are observed either in baking quality or the nutrient value of wheats from the differently manured plots.

If at Rothamsted, where rainfall and soil moisture are not so seasonal, erratic and precarious as in many parts of India, and where soil organic matter is high and the temperatures are low, farmyard manure has been useful in promoting an even and regular course of growth smoothing out seasonal variations in water and nutrients, the importance of organic matter and organic manures in India is obvious. Loss in yield is not the only injury which results from widespread defects and deficiencies in manuring. In the light of the information on the effect of manuring on the quality of the seed and the composition of the grain, it would appear that without suitable manuring crop growth would be poor and the seed produced for future crops will deteriorate. The result would be that cultivators would be raising poorer crops because of the inherent weakness of the seed, and also produce for the people food lacking or low in nutritive quality because of unsuitable manurial treatment.

Even if there should be difference of opinion in regard to generalisation on the necessity and importance of organic matter and organic manures in crop production, the greatest common agreement may, however, be found in the statement that under critical conditions organic matter and organic manures generally contribute to better yields both in quantity and quality. Among the critical conditions may be mentioned:

1. Hot dry periods when soil moisture and atmospheric humidity fall very low.
2. Soils containing excessive and harmful quantities of salts.
3. Soils with extremes in texture.
4. Soils deficient in organic matter and in one or more of the minor elements of plant nutrition.

If the above are accepted to be generally true for the great majority of the agricultural area in India, then the significance of the new knowledge is evident.

In countries like England, as well as in a very few spots in India, the critical conditions mentioned in 1 and 2 are very rarely met with; conditions 3 and 4 may occur occasionally but in many cases the organic matter is very much higher than that in average Indian soils. It is not to be expected, therefore, that the need for organic manurial dressings will be so marked in Europe and other countries, and yet marked benefit is observed there. It is, therefore, evident that it is here in India that these factors should be investigated in the light of the newer knowledge.

From the nutrition point of view there should be investigation of the biological nature and composition of the different vegetable food stuffs which, on the basis of their calorific value, protein, vitamin and mineral content and acid-base ratio, may be classified into main groups such as:

1. Cereal grains (superior and inferior).
2. Pulse grains.
3. Oil-seeds.
4. Tubers and roots.

5. Green vegetables.
6. Fruits.
7. Fodders.
8. Hays.

Fertiliser experiments carried out on the basis of the classification as above should afford an insight into the influence of manuring on the important factors which determine their value as foods.

It is true that there is now enough knowledge for remedying dietary defects by supplements, and that food-supply in quantity and variety can be augmented by improvements in distribution But there are large sections of subsistence farmers and agricultural labourers who cannot afford to buy food in addition to what they produce or obtain in their locality. Increase in population and pressure on land tends to put a limit on the production of animal products. It can be realised that for the amount of vegetable food consumed only 15 to 20 per cent efficiency is obtained in the form of animal food products. Prevention of defects at the source of production is better than remedying defects afterwards.

The significance of this knowledge and the responsibility of the agricultural and nutritional investigators are evident. Even in the short space of two decades we have clear indications of the trend of events. About twenty-five years ago we were of the opinion that mineral fertilisers had solved the problem of agricultural production. Intensive agriculture in the past twenty-five years has awakened Europe and America to realise the value of organic manures, and they now join India in the cry to conserve and use organic matter—a cry which was not seriously considered till recently. The meaning is clear not only to Indian agriculture but to world agriculture. Under intensive farming in temperate regions whose soils and farming systems are comparatively much younger that those in India, the soils are likely to become in course of time mineral soils similar to those of India and China, and it is here that research in India, which is concerned mostly with mineral soils, is likely to be of worldwide interest.

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ABSTRACTS

PHYSIOLOGICAL STUDIES ON THE WHEAT PLANT. V. DIURNAL VARIATIONS OF TOTAL NITROGEN AND AMINO-ACID NITROGEN IN *Triticum vulgare*.

By Shri Ranjan and Santosh Kumar Basu, Botany Department, Allahabad University.

1. Samples of stems and leaves were separately obtained from the wheat plants at 8 a. m., 12 noon and 4 p. m. The total nitrogen and amino-acid nitrogen of the above samples were estimated. It was observed that the amounts of total nitrogen and amino-acid nitrogen in leaves rise and reach a maximum value by noon, and thereafter decrease. In stems the total nitrogen varies directly with the variations in the total nitrogen of the leaves.

2. Excised leaves when kept away from light showed a rapid fall in the total nitrogen content from morning to moon, while the nitrogen in the stem remained constant throughout.

3. When the leaves were injected with 2% glucose solution and kept in dark, the total nitrogen increased towards noon and thereafter it fell off. The nitrogen of the stem, however, showed throughout a slight rise.

4. The total nitrogen in the leaves when injected with 2% glucose Shive's solution, and kept in dark showed a marked increase towards noon. The increase however, fell off towards evening

5. In discussing the results one finds that in the day the carbohydrates increase, as a result of photosynthesis, so also the total nitrogen. But how is it that there is such a relationship? Ranjan has shown that respiration increases in light to a marked extent. We beg to submit that the increased energy thus released in light brings about the synthesis of proteins. This is substantiated by experiments in plants kept in dark but injected with glucose and Shive's solution. In this case also total nitrogen rapidly increases. Here again with the injection of glucose the respiration rate rises rapidly, and the increased energy given out in this exothermal reaction is enough to cause the synthesis of nitrogen from the NO_3 taken either from the soil or from the Shive's solution injected. Thus light plays only an indirect part in the synthesis of proteins.

THE USE OF FIELD OBSERVATION IN CLASSIFYING FUNGI IMPERFECTI.

By G. Watts Padwick, Imperial Agricultural Research Institute, New Delhi.

The intimate relationship between taxonomy and applied mycology is emphasised. It is pointed out that increase in knowledge and classification of that knowledge go hand in hand, and that without the one the other dies. Our systematics should therefore be arranged in such a way as to take into account all aspects of biological knowledge.

The use of ecology in the classification of perfect fungi is discussed It is seen that although superficial examination would suggest that fungi are classified into classes, orders, families, genera, and species purely on the basis of morphology, in fact they form, in many cases, distinct ecological groups. A number of examples are given. The Chytridiales, for instance, by virtue of the part played by zoospores in their life-history, are moisture-loving organisms, the Saprolegniales are fresh water fungi with one or two exceptions. The Peronosporales contain many highly specialized parasitic forms. The Zygomycetes form less distinctive ecological groups. All the Promycetes contain highly specialized forms and a good deal is known of their breeding behaviour. Some of the

Eubasidiomycetes, such as the Thelephoraceæ, Polyporaceæ and Hypochnaceæ contain specialized parasites. The Ascomycetes contain some groups, such as the Argyriales, Laboulbeniales, and Erysiphaceæ in the Perisporiales with distinctive ecological relations, and others in which these tendencies are much less developed.

In the Fungi Imperfecti the Phomales and Melanconiales lend themselves fairly well to study under natural conditions, but there has been a strong tendency to name new species merely on the basis of the host-plant attacked without sufficient comparison with other known species of the same genus and without experimentation to determine the host range. In due course probably many will be found to be merely synonyms. The Moniliales are often unsuitable for field study because of their microscopic size, their unsuitability for preservation, and their impurity. Consequently, they have been described in many cases only from cultures on agar. Their appearance in such cultures often bears no resemblance to their appearance in nature, and in fact, in many cases we scarcely know what the fungi do look like under natural conditions, especially those which occur on the soil. A wider application of field observation in their study and of description from naturally occurring material checked and aided by pure-culture studies, is advocated.

A NEW TYPE OF PLACENTATION. *By V. Puri*, Meerut College.

While studying the gynaeceum constitution in the various families of the order Rhoeadales the author has come across a condition of the carpel which is not yet reported outside this Order. In some cases all the carpels, in others only the alternating ones, become 'solid' after gradual reduction and final collapse of their loculi. During this process of reduction the ovules of the carpels are expelled into the 'central cavity' and the margins of the same carpels fuse together. This indeed is a unique position for the ovules, for in closed carpels the ovules never lie outside the loculus of the carpel which bears them.

This mode of placentation is to be clearly distinguished from parietal and axile placentation. In the former case each placenta is formed at the point of fusion of the two adjacent margins of two carpels and ovules lie in the common 'central cavity'. In axile placentation a placenta is borne on the fused margins of the same carpel and the ovules lie within the loculus of that very carpel. But in the case under discussion a placenta is formed by an individual carpel and not by $\frac{1}{2}+\frac{1}{2}$ carpels as in parietal placentation and yet the ovules are contained in the common central cavity. For such a placentation the name *Extra-carpellary Placentation* is suggested by the author. This occurs in the Moringaceae, Cruciferae, Capparidaceae and some Papaveraceae. Further, a more restricted use has been suggested for the term 'loculus'.

SOMATIC CHROMOSOMES OF *PHASEOLUS RADIATUS* LIN. AND *PHASEOLUS MUNGO* LIN. ROXBURGHII PRAIN. *By S. P. Naithani*, Botany Department, Allahabad University.

The cytology of the following two species of *Phaseolus*—*P. radiatus-mung*, and *P. mungo-urad* was undertaken by the author. A number of plates of the somatic chromosomes of both the species were examined but the author was unable to confirm Rau's observations, who counted 12 pairs of chromosomes in the somatic tissue. The diploid number of chromosomes in all the types of both the species were found to be 22. This number is in full agreement with the number of chromosomes reported in other species of the genus *Phaseolus*. The chromosomes are very small. No morphological differences were noticed in the chromosomes of the different varieties of the same species. The chromosomes,

however, differ among themselves some being slightly curved other V- or J-shaped. The chromosomes in *mung* are slightly bigger than that of *urad*. No satellited chromosomes were observed in either species. Pro-chromosomes were not found in any of the species.

THE INFILTRATION OF GOLGI BODIES AND MITOCHONDRIA FROM THE FOLLICULAR EPITHELIUM TO THE EGG. *By D. R. Bhattacharya*, Zoology Department, Allahabad University.

The fact that certain small particles infiltrate from the follicular epithelium to the egg was first hinted at by Waldeyer in 1870. The author while working on the Tortoise egg in 1924, discovered that at least some of these particles were Golgi bodies. The same year, Brambell also discovered this phenomenon in the fowl. Since then the infiltration of Golgi bodies and Mitochondria from the follicular epithelial to the egg has been established in a large number of animals. A general account of this phenomenon in the animals examined so far will be given in this paper.

ON THE POSSIBLE PHYLOGENY OF THE DIGENEA. *By H. R. Mehra*, Zoology Department, Allahabad University.

The life-history studies have established beyond doubt that all the digenetic trematodes have a complicated life-history with alternation of paedogenetic parthenitae in the molluscan host and the sexual marita in the vertebrate host. Sinitsin's view that Gastropoda and parthenitae were the first to appear in the evolution of the parasitism in digenetic trematodes is discussed. The parthenita according to him possesses some of the characteristics that the ancestor of the Digenea possessed. On the basis of the view of the cell-constancy Sinitsin suggests the separation of the Digenea from the Monogenea and believes that the former are more closely related to the Rotifera and Arthropoda. This view is contested and the view by Looss and Mordvilko that the original trematode ancestor entered a vertebrate and had a life-cycle without a molluscan host seems acceptable.

The various lines of evolution culminating in a number of superfamilies and families of the modern Digenea are traced and the problem of host specificity discussed. The constancy of certain characters of the larvae and the adults for establishing the large taxonomic divisions is discussed, and it is suggested that the subdivision of the Digenea into the suborders Gasterostomata and Prosostomata should be dropped. The conclusion is drawn that a sound taxonomic system of the Digenea must be based upon the comparative anatomy of all stages in the life-history and further progress in the knowledge is necessary to achieve this end.

OBSERVATIONS ON THE DEVELOPMENT OF LIVER, PANCREAS AND PROSTATE GLANDS IN MAMMALS. *By M. A. H. Siddiqi*, King George's Medical College, Lucknow.

The development of Liver and Pancreas from the Endodermal tube is an established fact.

The urethra into which the ducts of Prostate gland open is developmentally a structure to which both the Ectoderm and Endoderm contribute. The extent to which these two Primary germ layers contribute is still not wholly clear. The close similarity between the development of Prostate on the one hand and Liver and Pancreas on the other is therefore full of interest.

Animal Husbandry and Crop Planning in India. *By K. C. Sen and S. C. Ray*, Imperial Veterinary Research Institute, Izatnagar.

The object of this paper is to draw attention to some of the causes which hamper the development of a healthy livestock industry in this country. It is realised by all public health workers that if the nutritional level of the population has to be raised, one of the fundamental necessities is a well established dairy industry in the country. The direct effect of an abundant supply of good quality milk will be an increase in the consumption of milk and milk products, enough of which are not available at present whereby sufficient protective food substances and animal protein of high biological value could be consumed by the average population. Apart from the obvious effects of animal products in improving the public health, a flourishing animal industry for this country means the supply of better quality bullocks which will raise the level of agricultural production.

In order to ensure the optimum conditions in our livestock industry, we must be able to provide sufficient feeding stuffs for the animal. This is not available at the present moment and it has been found that we can obtain about 55% of the food required from our organised supply, namely, mostly as by-products of arable agriculture. The problems which arise out of this food shortage are as follows:

(*a*) The animals suffer from under-nutrition or various types of malnutrition which has lowered their productive efficiency.

(*b*) As the available food-supply is deficient, it is of prime necessity to increase the production of fodder to make good the shortage.

(*c*) The increase in the fodder production can be effected by (1) improving the yield per acre or (2) by increasing the acreage under fodder production.

A study of the above points show that excepting the Punjab and Bombay, in most of the major provinces the acreage under fodder crop is only about 2 per cent of the total area available for cultivation. Calculating in terms of fodder requirement for the cattle population of these provinces, about 20 per cent of the present total acreage will be required to grow the necessary fodder crops. This increased acreage has to come either at the expense of some of the crops that are being grown for human consumption and non-food cash crops for industrial purposes or by bringing extra land under cultivation. What is therefore required is a proper understanding of the problem and the recognition of the fact that our existing agricultural policy needs recasting. The position is all the more difficult as the feeding problem has to be solved on a regional basis. For instance, under normal conditions, the Punjab and Bombay may probably be able to meet the food requirements, but provinces like the U. P., Madras, C. P. and Berar, and Bihar & Orissa would require an extra area of over 5 million acres under cultivation solely for fodder crop production, and Bengal would need over 9 million extra acres.

If additional land is not available for fodder production, one has to consider how far one can reappropriate the land which is already under cultivation for human food and non-food cash crop. It must be understood that in this country, animals and human beings are constantly competing for the available land and with the tendency of the population increasing, this competition will become keener. However, a balance has to be kept somewhere. Sufficient area must be reserved for the production of animals' food. A successful animal industry is a pivot round which the prosperity and success of agricultural operations so largely depends. In the interest of national health, the question of food-supply for the animals demands urgent consideration and a lead must be given by the scientific workers for a proper crop-planning programme.

NITROGEN FIXATION UNDER STERILE CONDITIONS. *By N. R. Dhar and E. V. Seshacharyulu,*
Indian Institute of Soil Science, Allahabad.

In order to throw light on the mechanism of nitrogen fixation experiments were carried on by mixing different energy materials with sterile soil or oxides like those of zinc, aluminium, iron, manganese, nickel, cobalt, etc., and exposing them to light or kept in the dark under completely sterile conditions either in quartz or glass flasks.

It is highly interesting to note that the nitrogen fixed per gram of carbon oxidised under completely sterile conditions in soils in quartz flasks is 12·2 mgm. in light and 4·8 mgm. in the dark.

Similarly, from the experiments carried on in pyrex glass, which cuts off more light, especially the ultraviolet, than quartz, the mean nitrogen fixation is 10·74 mgm. per gram of carbon oxidised under perfectly sterile conditions in light in soil whilst in the dark the fixation is 4·5 mgm. The order of these fixations under sterile conditions is practically the same as obtained without sterilisation in soils.

It appears, therefore, that the efficiency of nitrogen fixation, whether the soil contains Azotobacter or is sterile, is practically the same. In other words, the means by which the energy material is oxidised and the energy is made available does not affect the efficiency of the process.

When the energy materials are added to the soil, they are oxidised with the liberation of energy, and this energy is utilised in nitrogen fixation under ordinary conditions. In natural conditions the energy materials are oxidised on the soil surface and also oxidised by the living organisms. But under sterile conditions, the micro-organisms are destroyed and the phenomenon of oxidation is a non-biological surface reaction. But the efficiency of the two processes, as far as the nitrogen fixation is concerned, is of the same order in soils. Hence we are forced to conclude that nitrogen fixation can take place in as efficient a manner as possible in soils as well as in surfaces in the same way as in natural conditions in presence of living organisms.

From our results it is clear that the amount of nitrogen fixation per gram of carbon oxidised with surfaces like ZnO, Al_2O_3, Ni_2O_3, CoO, MnO_2, Fe_2O_3 etc. with glucose as energy material is much greater than with soil under comparative conditions, both in light and in the dark as well as in the sterile and unsterile conditions. These results showing that nitrogen fixation is possible with pure surfaces both in light and in dark and that the efficiency of this process is greater with oxides than in soil are of fundamental importance. For nitrogen fixation neither soils nor bacteria are absolutely necessary. What really seems indispensible is a suitable surface where oxygen, nitrogen and an energy material are properly absorbed and are in intimate contact.

The energy material in contact with oxygen is oxidised on the surface and liberates energy necessary for the combination of nitrogen and oxygen. When light acts on the system a part of it is absorbed and causes a greater fixation of nitrogen. Hence in all cases the fixation of nitrogen is greater in light than in dark.

We have emphasised that the nitrogen fixed does not remain in the combined state for a long time because the combined nitrogen has a tendency to undergo oxidation in air specially in light first into ammonia, then into nitrite and finally into nitrate. In this process there is always the possibility of the formation and decomposition of the unstable substance, ammonium nitrite. In the soil there is already approximately 0·05% nitrogen, hence in soils this type of loss of nitrogen is likely to be more pronounced than in the case of the oxides which are completely free from nitrogen to start with. Hence with oxides the loss of nitrogen being less than in soil the efficiency of the process appears to be greater in oxides than in soil using the same energy materials under comparable conditions. Moreover with soils there is the greater chance of the formation of a compact mass specially on sterilisation and hence the chances of aeration are less in soil than in the oxides. It is well known that aeration plays an important part in nitrogen fixation. This type of loss of nitrogen

in the gaseous state is inevitable when either nitrogenous substances are formed in the soil, or are added to it in the form of manures like ammonium sulphate, oil cakes, cowdung, blood, urea, etc., and has been reported by different workers all over the world.

Do Non-Leguminous Plants Appropriate Atmospheric Nitrogen. *By N. D. Vyas*, Imperial Agricultural Research Institute, New Delhi.

That the plants require nitrogen for their metabolism is an axiomatic truth and that some of the plants like legumes, possess the power of utilising atmospheric nitrogen, through the agency of certain microorganisms, is also a universally recognised fact but whether non-leguminous plants are endowed with the same quality or not is yet a very disputed question. Therefore, in order to fathom out the truth a series of experiments were carried out at the Imperial Agricultural Research Institute. The results are presented in the paper.

The investigations were carried out with maize, a cereal, under field conditions as well as under controlled conditions in the laboratory.

Six years' trial under field conditions revealed that in four years there was a significant evidence of appropriation of atmospheric nitrogen by maize while in two years there were losses of insignificant amounts of original nitrogen.

Pot culture experiments with soil or with sand + nitrogen-tree-nutrient solution presented positive evidence of appropriation of atmospheric nitrogen. Similar was the case with water culture experiments.

Whether such fixation was through bacterial agency, as is the case with legumes, or whether it was independent in itself was further examined by special bacteriological tests, described in the paper. It has been found that such appropriation in the case of maize is not directly connected with bacterial association as is the case with legumes. The experimental evidence reveals that such power is possessed by the plant itself. Indirectly, its root secretions do play a part in stimulating nitrogen fixing microorganisms of soils. It has been found that in the presence of maize root secretions the amount of nitrogen fixed by soil organisms in Ashby's mannite solution was 15 to 20% more than in the control.

Production of Fuel Gas from Organic Waste Materials by Anaerobic Fermentation. *By S. V. Desai*, Imperial Agricultural Research Institute, New Delhi.

A lot of attention has been drawn to the preparation of compost manures from farm wastes by aerobic fermentation since the impetus given to the process by Howard's publication and it is forgotten that all aerobic processes of fermentation are wasteful inasmuch as the carbon, which is being burnt by oxidation to carbon dioxide, is not harnessed to do any work.

As against aerobic process of fermentation a very important and efficient process of anaerobic fermentation does exist and though on large-scale operation its usefulness is fully utilized, the small-scale cottage plants for utilizing economically the farm wastes are still unthought of.

The anaerobic decomposition of organic wastes for production of fuel gas and manures is well known. Researches on these lines have been stimulated by the development of the method of treating sewage in which the settleable organic solids are digested anaerobically by bacterial seed-beds for producing large quantities of gas having a relatively high calorific value. There are some difficulties in applying *ad hoc* the sewage-sludge digestion process to fibrous farm wastes which usually float on the surface of the fermentation tanks, and the nitrogen content of these waters is generally low in comparison to sewage and sludges. Further the size of particles that are to be fermented has a very

great effect on the efficiency of the fermentation and the farm wastes as such are of such a great size that some preliminary mechanical process has to be installed to break down the raw materials.

The experiments were primarily started to find out how much fuel gas could be efficiently obtained in a short time from such farm wastes as straws, dry leaves, dry sludge, farm litter, celluloses, etc. At first bacterial seed-beds were established in two-litre bottles by incorporating lake mud with straw powder, some ammonium sulphate and $CaCO_3$. Sewage sludge was also added and the bottles were sealed with two openings, one for collecting and measuring the gas evolved and the other for adding the material that was being tested. The bacterial seed-bed took some time in getting efficiently going. A month to six weeks elapsed in which further addition of straw was made from time to time without in any way introducing any oxygen. The process which started slowly at first became quite quick, the major portion of the material added being decomposed and evolved as gas in a five days' time.

The temperature at which the evolution took place rapidly was in the neighbourhood of 38 C. Lower temperatures decreased the efficiency while higher temperatures up to 48 – 50°C did not materially increase it.

The following table shows the amount of gas in cubic feet evolved by 1 lb. of the dry material and the time taken for the evolution :

		Gas in cu. ft.			N. in the material %
1.	Straw Powder (Wheat).	15·0	7	days	0·26
2.	Activated Sludge (Wet).	8·0	10	,,	1·56
3.	,, ,, (Dry).	10·0	10	,,	2·30
4.	Filter Paper.	·6·0	21	,,	0·00
5.	Dry Leaves.	7·0	10	,,	1·30
6.	Sugarcane Trash.	12·0	8	,,	0·22
7.	Maize Straw.	13·0	11	,,	0·29

It would be seen from the table that the materials like straw produce much more gas than materials like sludge and dry leaves though the latter contain much more nitrogen than the former. As the nitrogen was supplied in the form of inorganic nitrogen as ammonium sulphate, the nitrogen of the materials employed had no bearing on the amount of gas evolved. Nitrogen so supplied was nearly 1 mgm. per gram of the substance, *i.e.*, 1 lb per 1000 lbs. of the material.

The fuel gas evolved was analysed to arrive at the calorific value of the gas and the gas evolved by the different materials was analysed to find out the composition of the gas and how it was affected by the composition of the materials employed. It was found that the composition of the fuel gas more or less depended on the variety of the bacterial flora of the seed-bed and the composition was almost similar in each case, as shown by the table below :

Material	Composition of the gas %		
	CH_4	H_2	CO_2
Dry leaves.	44·44	10·78	44·78
Sugarcane Trash	45·44	10·23	44·33
Maize Straw	45·94	10·26	43·83
Activated Sludge	43.82	11·28	45·90
Straw Powder	46·42	9·88	44·70

As calculated from the evolution of gas 85% of the carbon content of materials like straw are being converted into the gaseous form by this type of fermentation.

All the nitrogen of the fermented material is being conserved in the bacterial seed-bed, and after a time no addition of nitrogen material like ammonium sulphate is necessary. The nitrogenous materials are necessary only in the beginning to set up the bacterial bed, later on any material added goes on to increase the nitrogen contents of the fermented material. Part of the fermented materials were occasionally taken out and dried. These dry easily and are without any obnoxious smell and contain a fair percentage of nitrogen in an easily nitrifiable state.

The calorific value of the gas is very high. It burns with a steady colourless flame which is intensely hot. The CO_2 present in the gas mixture may be eliminated by washing through lime suspension so that the calorific value is increased.

In the foreign countries where the latest methods of sewage purification are employed, subsidiary fermentation tanks for anaerobic fermentation of the precipitated organic sludge are erected and these tanks provide the fuel gas which not only supplies all the power necessary to run the whole sewage plant, but which can supply lighting facilities in and about the area covered by the factory.

It would be thus seen that if this process of mass fermentation be adopted in a modified form by farmers and the materials of farm wastes be utilized by anaerobic fermentation to produce fuel gas it would give him all the power and fuel necessary for his household purpose as well as to run machinery for agricultural operations. In addition very good manure would be available for his lands from the spent materials.

A NOTE ON AN IMPORTANT VIRUS DISEASE OF POTATOES IN INDIA. *By B. P. Pal*, Imperial Agricultural Research Institute, New Delhi.

A description is given of the important "mosaic" disease of the Phulwa (= Patna White) variety, which has been kindly identified for the writer by Dr. R. N. Salaman as being caused by the potato virus Y (= Solanum virus 2 of Kenneth Smith). Observations at New Delhi showed that the incidence of disease was greater in earlier plantings than in later ones and that rogueing of diseased plants was effective in reducing the incidence of the disease.

THE PROBLEM OF SELF-STERILITY AND PLANT-BREEDING. *By S. Ramanujam*, Imperial Agricultural Research Institute, New Delhi.

The phenomenon of self-sterility is explained from the points of view of its occurrence in nature and inheritance. The practical implications of a knowledge of the genetics of self-sterility are emphasised and a preliminary account of work on this problem for breeding in self-sterile *Brassicæ* is given.

STUDIES IN THE GENUS *PHYTOPHTHORA*. *I.* FRUIT-ROT AND A SEEDLING DISEASE OF SOLANUM MELONGENA (Egg plant), *By M. Mitra*, Imperial Agricultural Research Institute, New Delhi.

Fruits of brinjal showing brownish to dark brown spots were noticed in several vegetable shops in Delhi. Seedlings also were observed to suffer from the same disease. On isolations a species of *Phytophthora* was found. The fungus was isolated and morphological studies were carried out. The damage done to the fruits was estimated several times and it was noticed that white variety of brinjal are more susceptible and the infection was up to fifty per cent during the end of 1939 and 1940.

The disease starts from any part of the fruit especially from the calyx region. In the beginning the spots show water-soaked appearance. In serious cases the whole fruit rots and falls down.

The disease was first observed in 1918 in Philippine Islands and was named as *P. milangina.* Later on Ashby (formerly Director of Imperial Mycological Institute, Kew) amended the description of *P. parasitica* Dast. and placed it in his sub-group *P. parasitica* Dast. (em.) Ashby (*Macrospora*).

The fungus can infect potato and tomato as well and can survive in the soil for at least a year.

It forms papillate sporangia and at 20°C the measurement is $21 - 65\mu \times 16 - 40\mu$ with an average of $40{\cdot}3 \times 26{\cdot}5\mu$. Chlamydospores are terminal or intercallary, amber colour and in diameter $18 - 40\mu$ with an average of $26{\cdot}19\mu$. Oospores are spherical, yellowish brown, thick walled and in size $16{\cdot}5 - 37\mu$ with an average of $26{\cdot}2\mu$. Anthredia are amphigynous. The identification was confirmed by Professor Ashby.

This is the first record of the occurrence of this disease from India.

STUDIES IN THE GENUS PHYTOPHTHORA. II. A NEW BLIGHT DISEASE OF POTATO AND TOMATO

By M. Mitra, Imperial Agricultural Research Institute, New Delhi.

So far it was known that *Phytophthora infestans* de Bary is the cause of 'late blight' disease of potato. In August, 1929 diseased leaves of potato were received from the Potato-Breeding Sub-station, Simla, and supposed to be infected with *P. infestans.* The fungus was isolated and morphological studies were carried out on several media. The writer immediately suspected that it was not *P. infestans* as *P. infestans* cannot tolerate a temperature above 87°F. Further study showed that it was *P. parasitica* Dast. (Sub-group *Microspora*). Cultures were sent to Professor Ashby (formerly Director, Imperial Mycological Institute, Kew) and the identification was confirmed. During August, 1940 infection experiments were carried out at Simla on 163 varieties of potato plants on both young and mature and also on tomato plants and fresh isolations were made and it was found that isolations made at Delhi from potato plants received from Simla and at Simla from potato and tomato plants naturally infected were identical. The fungus was found to be more vigorous on young plants. The results of the experiments made at Simla are as follows :—

Number of varieties of potato plants showing	no infection ...	35
,, ,, ,, ,, ,,	very mild infection ...	19
,, ,, ,, ,, ,,	mild infection ...	23
,, ,, ,, ,, ,,	fair infection ...	20
,, ,, ,, ,, ,,	very fair infection ...	26
,, ,, ,, ,, ,,	bad infection ...	16
,, ,, ,, ,, ,,	very bad infection ...	5
,, ,, ,, ,, ,,	which died of infection ...	19

Infection experiments were also carried out in pots, the soil being infested with inoculum cultivated on corn-meal soil medium. The results were positive ; either the tubers rotted or the young plants died.

In Delhi tubers of 205 varieties or hybrids were inoculated which were received from Simla and it was found that 117 varieties were either resistant or almost resistant to *P. parasitica.*

In culture anthredia were found to be amphigynous and were formed in four-month old culture tubes. Sporangia typically papillate and the average measurement is $44{\cdot}9 \times 27{\cdot}1\mu$. The average diameter of chlamydospores and oospores is $36{\cdot}5\mu$ and 19μ respectively.

This is the first record of *P. parasitica* causing blight of potato and tomato.

APPENDIX 5

Office-Bearers and Members of the Council of the National Academy of Sciences, India, for the Year 1940

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D. S. Kothari, M Sc (Alld.), Ph.D. (Cantab.), F.N.I., F.N.A Sc.

Foreign Secretary

N. R. Dhar, D.Sc. (Lond. & Paris), F.I.C., F.N I., F.N.A Sc., I E S.

Other Members of the Council

Bawa Kartar Singh, M.A. (Cantab.), Sc.D. (Dublin), F.I.C., F.N.I., F.N.A.Sc., I.E.S.

H. R. Mehra, Ph.D (Cantab.), F.N.I., F.N.A.Sc.

A. C. Banerji, M.A. (Cantab.), M.Sc. (Cal.), F.N.I., F.N.A.Sc., I E.S.

Gorakh Prasad, D.Sc. (Edin.), F.N.A.Sc.

B. Sahni, Sc.D., D.Sc., F.R.S, F.G.S., F.N.I., F.N.A.Sc.

Ram Kumar Saksena, D.Sc. (Paris), F.N A.Sc.

Mohammad Abdul Hamid Siddiqui, M.A., M.S., F.R.C.S., D.L.O. F.N.A.Sc.

S. S. Bhatnagar, O B.E, D.Sc. (Lond.), F.N.I., F.N.A.Sc.

Saligram Bhargava, M.Sc. (Alld.), F.N A.Sc.

APPENDIX 6

List of Members

(Arranged Alphabetically)

*—Denotes a Fellow

†—Denotes a Fellow of the National Institute of Sciences, India

Date of Election		Alphabetical List of Members
31-10-35		Agarwal, Rai Amar Nath, Bari Kothi, Daraganj, Allahabad.
20-4-36	*	Ahmad, Sir Ziauddin, Kt., D.Sc., Muslim University, Aligarh.
20-4-35	† *	Ajrekar, Shripad Lakshman, B.A., I.E.S., 855 Bhamburda, Poona.
17-4-31	*	Asundi, R. K., M.Sc. (Bom.), Ph.D. (Lond.), Professor of Physics, Benares Hindu University, Benares.
1-1-30	† *	Bahl, K. N., D.Phil., D.Sc., Professor of Zoology, Lucknow University, Lucknow.
1-1-30	† *	Banerji, A. C., M.A., M.Sc., F.R.A.S., I.E.S., Professor of Mathematics, Allahabad University, Allahabad.
22-12-32	† *	Banerji, S. K., D.Sc., Meteorologist, Ganeshkhind Road, Poona 5.
20-4-36	*	Basu, N. M., D.Sc., 7 Bakshi Bazar Lane, Dacca.
17-4-31	*	Basu, Saradindu, M.Sc., Meteorologist, Meteorological Office, Civil Aerodrome, New Delhi.
31-10-35	† *	Bharadwaja, Yajnavalkya, Ph.D., Professor of Botany, Hindu University, Benares.
19-3-31	*	Bhargava, Saligram, M.Sc., Reader, Physics Department, Allahabad University, Allahabad.
17-4-31		Bhargava, Vashishta, M.Sc., I.C.S., Sessions and District Judge, Bulandshahr.
17-4-31		Bhatia, K. B., I.C.S., Sitapur.
17-12-35		Bhatia, M. L., M.Sc., Lecturer in Zoology, Lucknow University, Lucknow.
15-9-36		Bhatnagar, Birendra Kumar, B.Sc., Bank Road, Allahabad.
21-4-33	† *	Bhatnagar, S.S., D.Sc., O.B.E., Director, Board of Scientific and Industrial Research, Commerce Department, New Delhi.
20-12-34	*	Bhattacharya, A. K., D.Sc., Chemistry Department, Allahabad University, Allahabad.

Date of Election		Alphabetical List of Members
1-1-31	† *	Bhattacharya, D.R , M.Sc., Ph.D., Docteur ès Sciences, Professor of Zoology, Allahabad University, Allahabad.
20-4-36	† *	Bose, N.K , Ph.D., Mathematical Officer, Irrigation Research Institute, Lahore.
20-4-36	† *	Burridge, W., D.M., M.A. (Oxon.), Professor of Physiology, Lucknow University, Lucknow.
31-10-35		Chakravarty, D.N., D.Sc. Professor of Chemistry, College of Sciences, Nagpur.
10-5-35	† *	Champion, H. G., M.A , Sylviculturist. Imperial Forest Research Institute, Dehradun.
12-2-40		Charan. Shama. M.A., M.Sc. (Lond.). Professor of Mathematics. Agra College, Agra.
1-1-30	† *	Chatterji, G., Rai Bahadur, M.Sc., Meteorologist. Upper Air Observatory, Agra.
17-4-31	*	Chatterji, K. P., M.Sc., A.I.C., F.C.S., Reader, Chemistry Department, Allahabad University, Allahahad.
10-5-37		Chatterji, N. G., D.Sc., H.B. Technological Institute, Cawnpore.
17-12-35		Chaudhury, K. Ahmad, M.Sc, B.A. (Cal.), D.Sc. (Edin.), Wood Technologist, Imperial Forest Research Institute, Dehradun.
25-3-39	*	Chaudhri, Rafi Mohammad, M.Sc., Ph.D. (Cantab.), Reader in Physics, Muslim University, Aligarh.
10-5-37		Chaudhury, S. S., M.A., M.Sc., Kadam Kuan, P. O Bankipore, Patna.
10-5-35	† *	Chopra, Brvt. Col., R. N., C.I.E, M.B., I.M.S., Director, School of Tropical Medicine, Central Avenue, Calcutta.
31-10-35		Dabadghao, V. M., Physics Department, College of Science, Nagpore.
28-10-32	*	Das, A. K , D.Sc., Upper Air Observatory, Agra.
22-12-32	*	Das, B. K., D.Sc. (Lond.), Professor of Zoology, Osmania University, Hyderabad-Deccan.
19-3-31	*	Das, Ramsaran, D.Sc., Zoology Department, Allahabad University, Allahabad.
17-12-35	*	Das Gupta, S. N., M.Sc., D.I.C., Ph.D., Reader in Botany, Lucknow University, Lucknow.
29-7-36		Dass, A. T., Dharam, M.Sc., 13 Strachey Road, Allahabad.
20-4-36	† *	Datta, S., D.Sc., D.I.C., Professor of Physics, Presidency College, Calcutta.
15-9-37		Dayal, Jagdeshwari, M.Sc., Zoology Department, Lucknow University, Lucknow.

Date of Election	Alphabetical List of Members
29-2-32	Deb, Suresh Chandra, D.Sc., Research Physicist, Bose Institute, Calcutta.
17-4-31	* Deodhar. D. B., Ph.D, Reader, Physics Department, Lucknow University, Lucknow.
31-10-35	Desai, M S, M.Sc, Professor of Physics, M. T. B. College, Surat.
17-4-31	* Dey, P. K., M Sc., I.A S, Principal, Government Agricultural College, United Provinces, Cawnpore
1-1-30	† * Dhar, N. R., D.Sc., Docteur ès Sciences, F.I.C., I.E S., Deputy Director of Public Instruction, U. P., Allahabad.
31-10-35	Dube, Ganesh Prasad, M.Sc., Lecturer in Physics, Balwant Rajput College, Agra.
23-4-37	Dubey, V. S., M.Sc., Ph.D., D.I.C., Professor of Economic Geology, Hindu University, Benares.
28-10-32	Dutt, A. K., D.Sc., Research Physicist, Bose Research Institute, Calcutta.
17-4-31	† * Dutt, S. B, D.Sc., P.R S, Reader, Chemistry Department, Allahabad University, Allahabad.
19-3-31	* Dutt, S. K., M.Sc., D.Sc. (Alld.), Zoology Department, Allahabad University, Allahabad.
1-2-37	Gandhy, Darabshaw, J., Agricultural Engineering Department, U. P., Cawnpore.
20-4-36	* Ganguly, P. B, D.Sc., Professor of Chemistry, Science College, P. O. Bankipore Patna.
22-2-23	Ghatak, Narendranath, M.Sc., D.Sc., Chemical Assistant, Indian Stores Department, Government Test House, Alipore, Calcutta.
20-4-36	† * Ghose, S. L, Ph.D., Professor of Botany, Government College, Lahore.
8-11-30	† * Ghosh, J. C., D.Sc., Director, Indian Institute of Science, Bangalore.
19-3-31	† * Ghosh, R. N., D.Sc., Physics Department, Allahabad University, Allahabad.
19-3-31	* Ghosh, Satyeshwar, D.Sc, Chemistry Department, Allahabad University, Allahabad.
17-4-31	* Gupta, B. M., Ph.D., Deputy Public Analyst to Government, United Provinces, Lucknow.
10-5-37	Gupta, K. M., M.Sc, D.Sc, Professor of Biology, M. T B. College, Surat.
17-4-31	Higginbottom, Sam, D.Phil., Principal, Allahabad Agricultural Institute, Naini, Allahabad.

Date of Election		Alphabetical List of Members
10-5-37	† *	Husain, M. Afzal, Khan Bahadur, M.A. (Cantab.), M.Sc., I.A.S., Vice-Chancellor, Punjab University, Lahore.
21-12-36		Husain, Zahur, B.A. (Hons.), c/o K. B. Nur Husain Shah, D.S. Police, Amritsar (Punjab).
10-5-37	*	Ishaq, Mohammad, Ph.D., Physics Department, Muslim University, Aligarh.
20-4-36	*	John, C. C., Director of Fisheries, Travancore, S.I.
4-9-39	† *	Joshi, A. C., D.Sc., Assistant Professor of Botany, Hindu University, Benares.
3-4-34		Joshi, A. D., P.E.S., Lecturer, Training College, Lucknow.
10-5-37		Kalapesi, A. S., B.A., B.Sc., D.I.C., Ph.D., F.R.G.S., Professor, St. Xavier's College, Cruickshank Road, Fort, Bombay.
19-8-40		Kanitkar, K. P., M.A., M.Sc., Professor of Physics, Nowrosjee Wadia College, Poona 1.
15-9-31	† *	Kichlu, P. K., D.Sc., Physics Department, Government College, Lahore.
21-4-33		Kishen Jai, M.Sc., Professor of Physics, S. D. College, Lahore.
9-2-34	† *	Kothari, D. S., M.Sc., Ph.D., Professor of Physics, Delhi University, Delhi.
3-4-34	† *	Krishna, Sri, Ph.D., D.Sc., F.I.C., Forest Biochemist, Imperial Forest Research Institute, Dehradun.
5-10-33	*	Qureishy, A. M., M.A., Reader in Mathematics, Muslim University, Aligarh.
31-10-35		Lal, Rajendra Bihari, M.Sc., Assistant Traffic Superintendent, E.I.R., Chief Commercial Manager's Office, Calcutta.
1-1-30	† *	MacMahon, P. S., B.Sc. (Hons.), M.Sc., Professor of Chemistry, Lucknow University, Lucknow.
10-5-37		Mahabale, T. S., B.A., M.Sc., Biology Department, Gujarat College, Ahmedabad.
31-10-35	† *	Maheshwari, Panchanan, D.Sc., Head of the Biology Department, Dacca University, Dacca.
31-10-35		Majumdar, R. C., M.Sc., Ph.D., Bose Research Institute, 93 Upper Circular Road, Calcutta.
10-5-37		Mathur, A. P., M.Sc., D.I.C., D.Sc., Principal, Darbar Intermediate College, Rewa, C.I.
31-10-35	*	Mathur, K. N., D.Sc., Lecturer in Physics, Lucknow University, Lucknow.

Date of Election		Alphabetical List of Members
26-11-40		Mathur, L. P., M.Sc., D.Sc., Professor of Zoology, St John's College, Agra.
8-11-33	*	Mathur, Ram Behari, M.Sc., Ph.D., Professor of Mathematics, St. Stephenson College, Delhi.
17-12-35	† *	Matthai, George, M.A., Sc.D., F.R.S.E., I.E.S., Professor of Zoology, Punjab University, Lahore.
19-3-31	*	Mazumdar, Kanakendu, D.Sc., Physics Department, Allahabad University, Allahabad.
1-1-30	† *	Mehta, K. C., Rai Bahadur, Ph.D., M.Sc., Agra College, Agra.
19-3-31	† *	Mehra, H. R., Ph.D., Reader, Zoology Department, Allahabad University, Allahabad.
23-4-37	*	Misra, Avadh Bihari, D.Sc., D.Phil., Zoology Department, Hindu University, Benares.
20-4-35	† *	Mowdawalla, F. N., M.A., M.I.E.E., Mem. A.I.E.E., M.I.E., 301 Frere Road, Fort, Bombay.
19-3-40		Muley, B. N., M.Sc., Ph.D., Reader in Biology, D. J. Sind College, Karachi.
22-2-33	† *	Narliker, V.V., M.A., Professor of Applied Mathematics, Hindu University, Benares.
23-4-37	*	Nath, Raj, D.I.C., Ph.D., Head of the Geology Department, Hindu University, Benares.
12-2-40		Nigam, Ved Vrat, M.Sc., 52 Sir P. C. Banerji Hostel, Allahabad University, Allahabad.
20-4-35	† *	Normand, C.W.B., M.A., D.Sc., Director-General of Observatories, Poona.
31-10-35		Oak, V. G., M.Sc., I.C.S., Additional District Judge, Jhansi.
19-8-40		Pal, Nani Lal, M.Sc., Biology Department, Dacca University, Ramna, Dacca.
16-8-35		Pande, Kedar Dat, M.Sc., Lecturer, Training College, Agra.
17-4-31	*	Pandya, K. C., Ph D., St. John's College, Agra.
3-4-33	† *	Parija, P. K., M.A., I.E.S., Principal, Ravenshaw College, Cuttack.
10-5-35	† *	Pinfold, Ernest Sheppard, M.A., F.G.S., Geologist, The Attock Oil Co., Ltd., Rawalpindi.
18-9-35	*	Pramanik, S. K., M.Sc., Ph.D., D.I.C., Meteorologist, The Observatory, Alipur, Calcutta.
3-4-33	† *	Prasad, Badri Nath, Ph.D., Docteur ès Sciences, Mathematics Department, Allahabad University, Allahabad.

Date of Election		Alphabetical List of Members
5-10-33	*	Prasad, Gorakh, D.Sc., Reader, Mathematics Department, Allahabad University, Allahabad.
21-4-33	*	Prasad, Kamta, M A., M.Sc., I.E.S., Professor of Physics, Science College, P. O. Bankipore, Patna.
15-9-31	† *	Prasad, Mata, D.Sc., Royal Institute of Science, Bombay.
10-5-37		Prasad, Shiva Parbati, M.A. (Cantab.), Physics Department, Science College, P. O. Bankipore, Patna.
10-5-37		Rahimullah, M., M.Sc, Lecturer in Zoology, Osmania University, Hyderabad-Deccan.
10-5-37		Rahman, Wahidur, B.Sc. (Cal.), Professor of Physics, Osmania University, Hyderabad-Deccan.
20-12-34		Rai, Ram Niwas, M.Sc., Physics Department, Allahabad University, Allahabad.
15-9-37		Raina, Shyam Lal, M.Sc., Professor of Biology, S. P. College, Srinagar, Kashmir.
3-4-33	*	Ram, Raja, M.A., B.E., c/o. Lieut Col. R C. Wats, I.M.S., Haffkine Institute, Parel, Bombay.
10-5-37	*	Ramiah, K, Geneticist and Botanist, Institute of Plant Industry, Indore.
10-5-35	† *	Rangaswami Ayyangar, G. N., Rao Bahadur, B.A., I.A.S, Millets Specialist to the Government of Madras, Agricultural Research Institute, P.O. Lawley Road, Coimbatore.
19-3-31	*	Ranjan, Shri, M Sc. (Cantab.), Docteur ès Sciences, Reader, Botany Department, Allahabad ~~University, Allahabad~~
15-9-31	*	Rao, A. Subba, D.Sc., Zoology Department, Central College, Bangalore.
22-2-33	*	Rao, G. Gopala, B.A., M.Sc., D.Sc., Chemistry Department, Andhra University, Waltair.
20-4-35	*	Rao, I. Rama Krishna, M.A., Ph.D., D.Sc., Physics Department, Andhra University, Waltair.
14-3-34	† *	Rao, K. Rangadharma, D.Sc, Physics Department, Andhra University, Waltair.
22-2-33	† *	Ray, Bidhubhusan, D.Sc., 92 Upper Circular Road, Calcutta.
1-2-36		Ray, J. P., M.Sc., Professor, D. A. V. College, Dehradun.
10-5-37		Ray, Ramesh Chandra, D.Sc., F.I.C., Professor of Chemistry, Science College, P. O. Bankipore, Patna.
21-12-31		Ray, Satyendra Nath, M.Sc., Physics Department, Lucknow University, Lucknow.

Date of Election		Alphabetical List of Members
23-4-37		Rode, K. P., M.Sc., Assistant Professor of Geology, Hindu University, Benares.
29-2-32		Saha, Jogendra Mohan, M.Sc., Manager, Sitalpur Sugar Works, P.O. Digwara, Dist. Saran.
1-1-30	† *	Saha, M. N., D.Sc., F.R.S., F.A.S.B., F. Inst. P., P.R.S., Palit Professor of Physics, University College of Science, 92 Upper Circular Road, Calcutta.
1-1-30	*	Sahni, B., D.Sc., Sc.D., F.R.S., Professor of Botany, Lucknow University, Lucknow.
1-2-36	*	Saksena, Ram Kumar, D.Sc. (State-France), Lecturer, Botany Department, Allahabad University, Allahabad.
17-4-31	*	Sane, S. M., B.Sc., Ph.D., Reader, Chemistry Department, Lucknow University, Lucknow.
10-5-37	*	Sayeeduddin, M., M.A., B.Sc., Professor of Botany, Osmania University, Hyderabad-Deccan.
31-10-35	† *	Sen, Jitendra Mohan, M.Ed., B.Sc., Teacher's Dip., F.R.G.S., D.Ed., Principal, Krishnagar College, Krishnagar.
3-4-33	*	Sen, K. C., D.Sc., Officer-in-Charge, Animal Nutrition Section, Imperial Veterinary Research Institute, Izatnagar, U.P.
20-4-35	† *	Sen, Nikhil Ranjan, D.Sc., Professor of Mathematics, 92 Upper Circular Road, Calcutta.
17-12-35	† *	Sen Gupta, N. N., Ph.D., Professor of Psychology, Lucknow University, Lucknow.
20-12-34	*	Sen Gupta, P. K., D.Sc., Assistant Meteorologist, Indian Meteorological Office, Alipur, Calcutta.
19-3-31	*	Sethi, Nihal Karan, D.Sc., Agra College, Agra.
31-10-35	*	Shabde, N. G., D.Sc., Professor of Mathematics, College of Sciences, Nagpur.
10-5-37		Sharma, Dhyan Swarup, M.Sc., 40 Kaiserbagh, Lucknow.
31-10-35		Sharma, P. N., M.Sc., Physics Department, Lucknow University, Lucknow.
15-9-31		Sharma, Ram Kishore, M.Sc., Head of the Physics Department, Ewing Christian College, Allahabad.
18-9-33		Shukla, Janardan Prasad, M.Sc., Indian Institute of Sugar Technology, Cawnpore.
3-4-33	† *	Siddiqi, M. R., Ph.D., Professor of Mathematics, Osmania University, Hyderabad-Deccan.

Date of Election		Alphabetical List of Members
3-4-33	*	Siddiqui, Mohammad Abdul Hamid, M.A., M.S., F.R.C.S., D.L.O., Professor of Anatomy, King Edward Medical College, Lahore.
10-5-37	† *	Singh, Bawa Kartar, M.A. (Cantab.), Sc.D., F.I.C., I.E.S., Professor of Chemistry, Allahabad University, Allahabad.
17-12-35	*	Singh, Bhola Nath, D.Sc., Kapurthala Professor of Agricultural Botany and Plant Physiology, Hindu University, Benares.
10-5-37		Singh, T. C. N., D.Sc., Assistant Economic Botanist, In-charge, Botanical Section, Sabour (Bihar).
18-9-35	*	Srivastava, Bishwambhar Nath, M.Sc., D.Sc. (Alld.), Lecturer, Physics Department, Allahabad University, Allahabad.
4-9-39		Srivastava, Girja Dayal, M.Sc., Lecturer, Botany Department, Allahabad University, Allahabad.
19-3-31	† *	Srivastava, P. L., Rai Sahib, M.A., D.Phil. (Oxon), Reader, Mathematics Department, Allahabad University, Allahabad.
10-8-33	*	Srivastava, R. C., B.Sc. (Tech.), Sugar Technologist, Imperial Council of Agricultural Research, India, Cawnpore.
15-9-31	*	Srikantia, C., B.A., D.Sc. (Zurich), Medical College, Mysore.
19-12-32	*	Strang, J. A., M.A., B.Sc., Professor of Mathematics, Lucknow University, Lucknow.
17-4-31	† *	Sulaiman, Hon'ble Sir S.M., Kt., M.A., LL.D., D.Sc., Judge, Federal Court of India, Delhi.
20-4-36	† *	Sur, N. K., D.Sc., Meteorologist, Meteorological Department, Alipur, Calcutta.
17-12-35		Tandon, Amar Nath, M.Sc., D.Phil., Physics Department, Allahabad University, Allahabad.
9-11-35		Tandon, Prem Narain, M.Sc., I.C.S., Under-Secretary to Govt., Political and Applt. Department, Patna.
4-9-39		Tewari, Sri Govind, Capt., M.A., Mathematics Department, Allahabad University, Allahabad.
19-3-31	*	Toshniwal, G. R., M.Sc. (Alld.), D.Sc. (Alld.), Men. I.R.E., Physics Department, Allahabad University, Allahabad.
3-4-34		Varma, Rama Shanker, M.Sc., Christ Church College, Cawnpore.
9-2-34		Vaugh, Mason, B.Sc. (Ing.), Agricultural Engineer, Allahabad Agricultural Institute, Naini, Allahabad.
19-3-31	† *	Vijayaraghavan, T., D.Phil., Reader, Mathematics Department, Dacca University, Ramna, Dacca.

Date of Election		Alphabetical List of Members
20-4-35	† *	Vishwanath, B., Rao Bahadur, F.I.C., Director, Imperial Agricultural Research Institute, New Delhi.
20-4-35	† *	Wadia, D. N., M.A., B.Sc., F.G.S., F.R.G.S, Mineralogy Department, Columbo, Ceylon.
1-1-30	† *	Wali, Mohammad Ch., M.A., Ph.D., I.E.S., Professor of Physics, Lucknow University, Lucknow.

N.B.—The Secretaries will be highly obliged if the members will kindly bring to their notice errors, if there be any, in their titles, degrees, and addresses.

APPENDIX 7

List of Exchange Journals

INDIAN

Publishers	Journals
BANGALORE	
The Indian Academy of Sciences	Proceedings of the Indian Academy of Sciences, Section A
,,	,, Section B
The Indian Institute of Science	Journal of the Indian Institute of Science, Section A
,,	,, Section B
,,	Quarterly Journal of the Indian Institute of Science
,,	Current Science
Department of Electrical Technology, Indian Institute of Science	Electrotechnics
Society of Biological Chemists, India	Proceedings of the Society of Biological Chemists, India
BOMBAY	
Haffkine Institute	Report of the Haffkine Institute
CALCUTTA	
Asiatic Society of Bengal	Journal of the Asiatic Society of Bengal (Letters)
,,	Journal of the Asiatic Society of Bengal (Science)
,,	Year Book
,,	Journal and Proceedings of the Asiatic Society of Bengal
,,	Proceedings of the Indian Science Congress
National Institute of Sciences of India	Transactions of the National Institute of Sciences of India
,,	Indian Science Abstracts
,,	Proceedings of the National Institute of Sciences of India

Publishers	Journals
CALCUTTA	
National Institute of Sciences of India	Report of the Council of the National Institute of Sciences of India
Indian Association for Cultivation of Science	Indian Journal of Physics and Proceedings of the Indian Association for the Cultivation of Science
Bose Research Institute	Transactions of the Bose Research Institute
Indian Science News Association	Science and Culture
Indian Chemical Society	The Journal of the Indian Chemical Society
Oxford University Press	Indian Physico-Mathematical Journal
Calcutta University	Journal of the Department of Science
COONOR	
Nutrition Research Laboratories	Publications of the Laboratories (Publication discontinued from 1938)
MADRAS	
Department of Fisheries	Journals, Administration Report
Madras Government Museum	Bulletin of the Madras Government Museum, Natural History Section
NEW DELHI	
Industrial Research Bureau	Bulletin of the Indian Industrial Research
Imperial Council of Agricultural Research	Indian Journal of Agricultural Science
"	Indian Journal of Veterinary Science and Animal Husbandry
"	Scientific Monographs of the Imperial Council of Agricultural Research
"	Agriculture and Livestock in India
"	Annual Report
"	Indian Farming
NAGPUR	
Nagpur University	Nagpur University Journal

Publishers	Journals
HYDERABAD (DECCAN)	
Osmania University	Journal of the Osmania University
PATNA	
Philosophical Society, Science College, Patna	Bulletin of the Patna Science College Philosophical Society
POONA	
Indian Meteorological Department	Scientific Notes
"	Memoirs of the Indian Meteorological Department
"	Seismological Bulletin

FOREIGN

AUSTRALIA

ADELAIDE	
The Royal Society of South Australia	Transactions of the Royal Society of South Australia
EAST MELBOURNE	
Council for Scientific and Industrial Research	Journal of the Council for Scientific and Industrial Research
"	Pamphlet of the Council for Scientific and Industrial Research
"	Annual Report
Radio, Research Board Council for Scientific and Industrial Research	Bulletin of the Radio Research Board
MELBOURNE	
Royal Society of Victoria	Proceedings of the Royal Society of Victoria
"	Annual Report
SYDNEY	
Royal Society of New South Wales	Journal and Proceedings of the Royal Society of New South Wales

Publishers	Journals
AUSTRIA	
VIENNA	
Akademie der Wissenschaften	Anzeiger (Mathematisch-naturwissenschaftliche Klasse)
„	Anzeiger (Philosophisch-historische Klasse)
„	Almanach
BELGIUM	
BRUSSELS	
L'Academie Royale de Belgique	Bulletin de la Classe des Sciences
„	Annuaire de l'Academic Royale de Belgique
CANADA	
OTTAWA	
The Royal Society of Canada	Transactions of the Royal Society of Canada
„	Biological Sciences
The National Research Council	Annual Report
TORONTO	
The Royal Astronomical Society of Canada	Journal of the Royal Astronomical Society of Canada
VICTORIA	
The Dominion Astrophysical Observatory	Publications of Dominion Astrophysical Observatory
CHINA	
NANKING	
National Research Institute of Biology, Academia Sinica	Sinensia
Zoological Society of China, Academia Sinica	Chinese Journal of Zoology
National Research Institute of Chemistry, Academia Sinica	Memoir of the National Research Institute of Chemistry
SHANGHAI	
National Research Institute of Physics, Academia Sinica	Scientific Papers of the National Research Institute of Physics

Publishers	Journals
DENMARK	
COPENHAGEN	
Det. Kgl. Danske Videnskabernes Selskab	Mathematisk-fysiske Meddelelser
„	Biologiske Meddelelser
L'Academie Royale des Sciences et des Letters de Denmark	Mêmoires de l'acadêmie Royale des Sciences et des Letters de Denmark
Laboratoire Carlsberg	Comptes-Rendus des Travaux du Laboratoire Carlsberg
EGYPT	
CAIRO	
The Egyptian Medical Association	Journal of the Egyptian Medical Association
Head of the Faculty of Medicine	Tremetodes of Fishes from Red Sea
ENGLAND	
ABERDEEN	
Imperial Bureau of Animal Nutrition	Technical Communications
ABERYSTWYTH	
Imperial Bureau of Plant Genetics; Herbage Plants	Bulletins
ST. ALBANS, HERTS	
Imperial Bureau of Agricultural Parasitology	Helminthological Abstracts
„	Bibliography of Helminthology
CAMBRIDGE	
Imperial Bureau of Plant Genetics, School of Agriculture	Plant Breeding Abstracts
The Philosophical Society	Proceedings of the Cambridge Philosophical Society
EDINBURGH	
The Royal Society of Edinburgh	Proceedings of the Royal Society of Edinburgh

Publishers	Journals
HARPENDEN	
Imperial Bureau of Soil Science, Rothamsted Experimental Station	Technical Communications
,,	Soils and Fertilizers
,,	Reprints
,,	Reports
,,	Pamphlets
EAST MALLING, KENT	
Imperial Bureau of Fruit Production	Horticultural Abstracts
LONDON	
The Electrician, Bouverie House	Electrician
TEDDINGTON, MIDDLESEX	
The National Physical Laboratory	Reports of the National Physical Laboratory
,,	Collected Researches of the National Physical Laboratory

France

PARIS	
L'Institute Henri Poincaré	Annales de l'Institute Henri Poincaré
De La Station Biologique de Roscoff	Travaux de la Station Biologique de Roscoff
RENNES	
De La Société Scientifique de Bretagne	Bulletin de la Société Scientifique de Bretagne

Germany

BERLIN	
Preussischen Akademie der Wissenschaften	Sitzungsberichte Der Preussischen Akademie
Deutschen Chemischen Gesellschaft	Berichte Der Deutschen Chemischen Gesellschaft

Publishers	Journals
GOTTINGEN	
Gasellschaften Wissenschaften zu Gottingen	Nachrichten von der Gasellschaft der Wissenschaften zu Gottingen Mathematisch-Physikalische Klasse Fachgruppe I. Mathematik
„	„ II. Physik, Astronomie, Geophysik Technik
„	„ III. Chemie, einschl. Physikalische Chemie.
„	„ IV. Geologie und Minerologie
„	„ V. Geographie
„	„ VI. Biologie
„	Geschaftliche Mitteilungen
HEIDELBERG	
Heidelberger Akademie der Wissenschaften	Sitzungsberichte der Heidelberger Akademie der Wissenschaften, Mathematisch-naturwissenschaftliche Klasse
LEIPZIG	
Sachsische Akademie der Wissenschaften	Berichte der Mathematishe Physischen Klasse
„	Abhandlungen der Mathematisch-Physischen Klasse
MUNCHEN	
Bayerischen Akademie der Wissenschaften zu München	Sitzungsberichte der Mathematisch-naturwissenschaftlichen Abteilung

HOLLAND

Publishers	Journals
GRONINGEN	
Kapteyn Astronomical Laboratory	Publications of the Kapteyn Astronomical Laboratory
LEIDEN	
Kamerlingh Onnes Laboratory of the University of Leiden	Communications from the Physical Laboratory of the University of Leiden
	Communications from Kamerlingh Onnes Laboratory

Publishers	Journals
HUNGARY	
BUDAPEST	
Der Ungarischen Akademie der Wissenschaften	Mathematisher und Naturwissen schaftlicher Anzeiger
ITALY	
PALERMO	
Circolo Mathematico di Palermo	Rendiconti del Circolo Mathematico di Palermo
ROME	
International Institute of Agriculture	Monthly Bulletin of Agricultural Science and Practice
VENICE	
Centro Volpi Di Elettrologia	Bulletin of the Centro Volpi Di Elettrologia
JAPAN	
HIROSHIMA	
Hiroshima University	Journal of Science of the Hiroshima University, Series A
KEIJO	
Medical Faculty, Keijo Imperial University	The Keijo Journal of Medicine
KYOTO	
Physico-Chemical Society of Japan, Kyoto Imperial University	Review of Physical Chemistry of Japan
OSAKA	
The Faculty of Science, Osaka Imperial University	Collected Papers from the Faculty of Science
"	Collected Papers from the Faculty of Medicine
SAPPORO	
The Faculty of Science, Hokkaido Imperial University	Journal of the Faculty of Science, Series I, Mathematics
SENDAI	
Imperial University of Tohoku	Science Reports of the Tohoku Imperial University

Publishers	Journals
TOKYO	
The Imperial Academy	Proceedings of the Imperial Academy
The Institute of Physical and Chemical Research	Scientific Papers
The National Research Council of Japan	Japanese Journal of Mathematics
„	Japanese Journal of Botany
„	Japanese Journal of Physics
„	Japanese Journal af Astronomy and Geophysics
„	Report
„	Report of Radio Research
The Physico-Mathematical Society of Japan	Proceedings of the Physico-Mathematical Society of Japan

MANCHOUKUO

HSINCHING	
The Institute of Scientific Research	Report of the Institute of Scientific Research

~~NEW ZEALAND~~

WELLINGTON	
Royal Society of New Zealand	Transactions and Proceedings of the Royal Society of New Zealand

PHILIPPINE ISLANDS

MANILA	
Bureau of Sciences, Department of Agriculture and Commerce	Philippine Journal of Science

POLAND

CRACOVIE	
Académie Polonoise des Sciences et des Lettres	Comptes Rendus Mensuels des Séances de la classe des Sciences Mathématiques et Naturelles
	Comptes Rendus Mensuels des Séances de la classe de Médecine

Publishers	Journals
CRACOVIE	
Académie Polonoise des Sciences et des Lettres	Bulletin International, classe des Sciences Mathématiques et Naturelles, Śerie A : Sciences Mathématiques
"	Bulletin International, classe des Sciences Mathématiques et Naturelles, Śerie B : Sciences Naturelles (I)
"	Bulletin International, classe des Sciences Mathématiques et Naturelles, Śerie B : Sciences Naturelles (II)
"	Memoires, classe des Sciences Mathématiques et Naturelles, Śerie A : Sciences Mathématiques
"	Memoires, classe des Sciences Mathématiques et Naturelles Śerie B : Sciences Naturelles
"	Bulletin International, classe de Médecine
"	Memoires classe de Médecine
Polska Akademja Umiejetności	Starunia
"	Travanz Geologiques
WARSAW	
Société des Sciences et des Lettres de Varsovie	Comptes Rendus des Śeances, class I (jezykoznawstwa i historji literatury)
"	Comptes Rendus des Śeances, class II (historycznych, spolecznych i filozoficznych)
"	Comptes Rendus des Śeances, class III (matematyczno-fizycznych)
"	Comptes Rendus des Śeances, class IV (bilogicznych)
Polish Physical Society	Acta Physica Polonica

ROMANIA

Publishers	Journals
JASSY	
Universitatia Din Jasi, Seminarul Matmatic	Annals Scientifique

Publishers	Journals
SOUTH AFRICA	
CAPE TOWN	
Royal Society of South Africa	Transactions of the Royal Society of South Africa
SWEDEN	
LUND	
Kungl. Fysiografiska Sällskapets	Kungl. Fysiografiska Sällskapets Forhandlingar
STOCKHOLM	
Kungl. Svenska Vetenskapsakademie	Kungl. Svenska Vetenskapsakademiens Handlingar
UPPSALA	
Uppsala Universitet	Uppsala Universitets Årsskrift
SWITZERLAND	
GENEVA	
Société de Physique et d' Histoire Naturelle de Genève	Compte Rendu des Séances de La Société de Physique et d' Histoire Naturelle de Genève
UNION OF SOVIET SOCIALIST REPUBLICS	
KHARKOV	
Chaikovsakaya 16	Physikalische Zeitschrift der Sowjet-Union (*stopped after March, 1938*)
LENINGRAD	
The Akademie der Wissenschaften	Bulletin de l'Academie des Sciences Mathématiques et Naturelles
MOSCOW	
De l'Académie des Sciences de l'URSS	Comptes Rendus (Doklady)
De l'Académie des Sciences de l'URSS	Bulletin de l'Académie des Sciences de l'URSS classe des Sciences Mathématiques et Naturelles

Publishers	Journals
UKRAINE	
Academie des Sciences d'Ukraine, Kyive	Journal du Cycle Physique et de Chemie
"	Journal du Cycle Mathématique
"	Bulletin de la classe des Sciences Physique et Mathêmatiques

United States of America

Publishers	Journals
ALLEGHENY CITY	
Allegheny Observatory of the University of Pittsburgh	Publications of the Allegheny Observatory
BOSTON	
American Academy of Arts and Sciences	Proceedings of the American Academy of Arts and Sciences
"	Memoirs of the American Academy of Arts and Sciences
RIO DE JANEIRO	
Instituto Oswaldo Cruz	Memorias do Instituto Oswaldo Cruz
CALIFORNIA	
The Mount Wilson Observatory	Contributions from the Mount Wilson Observatory
"	Communications from the Mount Wilson Observatory
"	Annual Report of the Director of the Mount Wilson Observatory
University Library	Publications in Zoology, University of California
Lick Observatory, University of California	Lick Observatory Bulletin
CAMBRIDGE MASS.	
Massachusetts Institute of Technology	Journal of Physics and Mathematics

Publishers	Journals
CHICAGO	
The University of Chicago	Astrophysical Journal
LAWRENCE, KANSAS	
The University of Kansas	Science Bulletin
MICHIGAN	
Observatory Library, University of Michigan	Publications of the Observatory of the University of Michigan
NEW YORK	
Bell Telephone Laboratories	Bell Telephone System Technical Publications
American Telephone and Telegraph Company	Bell System Technical Journal
Roosevelt Wild Life Forest Experiment Station	Roosevelt Wild Life Annals
The American Museum of Natural History	American Museum Novelties
New York Academy of Sciences	Annals of the New York Academy of Sciences
American Institute of Physics	Review of Scientific Instruments
"	Journal of Chemical Physics
NEW HAVEN, YALE	
Astronomical Observatory of Yale University	Transactions of the Astronomical Observatory, Yale University
American Journal of Science	American Journal of Science
PHILADELPHIA	
The Franklin Institute of the State of Pennsylvania	Journal of the Franklin Institute
American Philosophical Society	Proceedings of the American Philosophical Society
Academy of Natural Sciences	Proceedings of the Academy of Natural Sciences of Philadelphia
	Miscellanea
	Library Annual Report

Publishers	Journals
WOODS HALE MASS.	
Marine Biological Laboratory Library	The Biological Bulletin
WASHINGTON	
The National Academy of Sciences	Proceedings of the National Academy of Sciences
„	Biographical Memoirs
Smithsonian Institute	Publications
Department of Commerce, National Bureau of Standard Library	Publications of the Bureau of Standards
The Commissioner of Fisheries	Publications
Carnegie Institute of Washington	Magnetic Observations of Sun-spots

SOUTH AMERICA

MONTEVIDEO—Uruguay	
Sociedad de Biologia de Montevideo	Archivos De La Sociedad Biologia De Montevideo

APPENDIX 8

List of Papers Communicated to the Academy During January, 1940—December, 1940

(Arranged Alphabetically)

1. Adsorption of Cations by a crystalline variety of Aluminium Silicate, by S. P. Srivastava, Chemistry Department, The University, Allahabad. (Communicated by Dr. S. Ghosh.)
2. Anatomical Studies in the Asclepiadaceæ, by M. Sayeed-ud-Din and M. R Saxena, Botany Department, Osmania University, Hyderabad-Deccan.
3. Annotated List of Helminths recorded from Domesticated Animals of Burma. Part III—Nematoda and Acanthocephala, by R. C. Chatterji, Helminthological Institute, Rangoon. (Communicated by Dr. H. R Mehra.)
4. Brief Note on the "Camel Spiders" (Galeodes) of the Hyderabad State, by M. Rahimullah, Zoology Department, Osmania University, Hyderabad-Deccan. (Communicated by Prof. D. R. Bhattacharya.)
5. Cellulose resources of the United Provinces for Paper and Rayon Manufacture, by Sikhibhushan Dutt, Prithvi Nath Bhargava and Roop Narain Mehrotra, Chemistry Department, The University, Allahabad.
6. Chemical Examination of the Essential Oil of *Mentha arvensis* or Pudina, by Brij Kishore Malaviya and Sikhibhushan Dutt, Chemistry Department, The University, Allahabad.
7. Chemical Examination of the Fixed Oil of the Seeds of *Lallemantia royleana* Benth or Tukhm-i-Malanga, by Ram Das Tiwari and Brij Kishore Malaviya, Chemistry Department, The University, Allahabad.
8. Chemical Examination of the Leaves of *Lantana camara* Linn., Composition of the Essential Oil, by Jagat Narayan Tayal and Sikhibhushan Dutt, Chemistry Department, The University, Allahabad.
9. Colour in relation to Chemical Constitution of the Organic and Inorganic Salts of Isonitroso-malonyl-guanidine : A correction, by Sikhibhushan Dutt, Chemistry Department, The University, Allahabad.
10. Composition of Patent Still Molasses Fusel Oil of Indian Origin, Part II, by Sikhibhushan Dutt, Chemistry Department, The University, Allahabad.
11. Composition of Patent Still Molasses Fusel Oil of Indian Origin, Part IV, by Sikhibhushan Dutt, Chemistry Department, The University, Allahabad.

12. Contribution to the Study of the Genus *Opisthorchis* Blanchard 1895, Part I —Description of the New Species and Sub-species, by Ram Krishna Mehra, Zoology Department, The University, Allahabad. (Communicated by Dr. H R Mehra.)

13 Contribution to the Study of the Genus *Opisthorchis* Blanchard 1895, Part II— Discussion on the Synonymy of the Genus *Opisthorchis Blanchard* 1895 and *Gomtia Thapur* 1930 and Key for the identification of the Species of the Genus *Opisthorchis*, by Ram Krishna Mehra, Zoology Department, The University, Allahabad (Communicated by Dr. H R Mehra.)

14. Cytological Studies in Cajanus. The Somatic Chromosomes and the Pro-Chromosomes, by S. P. Naithani Botany Department, The University, Allahabad. (Communicated by Dr. R. K. Saksena.)

15. Cytoplasmic inclusions in the Oogenesis of *Rhipicephalus sanguineus* (Latreille), by Ram Saran Das, Zoology Department, The University, Allahabad.

16. Determination of Soil Constants at Broadcast and Ultra High Frequency, by B. D. Toshniwal and G. R Toshniwal, Physics Department, The University, Allahabad

17. Electrical Method for Determining the Absorption Coefficient of Sound, by Chandra Kanta (Miss), Physics Department, The University, Allahabad. (Communicated by Dr. R N. Ghosh.)

18. Formation of Periodic Precipitate in the Absence of a Foreign Gel, by R. N. Mittra, Chemistry Department, The University, Allahabad. (Communicated by Dr. S. Ghosh.)

19. Formation of Periodic Precipitate in the Absence of a Foreign Gel, Part V— Ceric Hydroxide Sol, by R. N. Mittra, Chemistry Department, The University, Allahabad. (Communicated by Dr. A. K. Bhattacharya.)

20. Formation of Periodic Precipitate in the Absence of a Foreign Gel, Part VI, by R N. Mittra, Chemistry Department, The University, Allahabad. (Communicated by Dr. A. K. Bhattacharya.)

21 Importance of Growth-Promoting Substances in the Metabolism of *Pythium indigoferæ* Butler, by R. K. Saksena, Botany Department, The University, Allahabad.

22 Importance of the Primary Absorption Process in Photo Chemical Reactions, Part II, by A K Bhattacharya, Chemistry Department, The University, Allahabad.

23 Influence of Radiation on the rate of Respiration of Some Coloured Flowers, by Shri Ranjan and B. B. L. Saksena, Botany Department, The University, Allahabad.

24. Investigation of Aluminium Silicate Sols, Part I, by S. P. Srivastava and S. Ghosh, Chemistry Department, The University, Allahabad.

25. Leptotene thread. Chromomere or Chromonima, by S. P. Naithani, Botany Department, The University, Allahabad. (Communicated by Dr. R K. Saksena.)

26 Migration of the Para Halogen Atom in a Derivative of Meta-Cresol, Part II, by A. B. Sen, Chemistry Department, The University, Lucknow. (Communicated by Prof. S. M. Sane.)

27. New Distome *Enterohæmatotrema* N G. and a New Blood Fluke *Hemiorchis Bengalensis* N. Sp. belonging to the Family Spirorchidæ Stunkard and a New Species of the Genus *Dendritobilharzia* Skrjabin and Zakharow belonging to the Family Schistosomatidæ Poche, with Remarks on the Evolution of Blood Flukes, by H R. Mehra, Zoology Department, The University, Allahabad.

28. New Trematode Genus *Prosterogonionces* belonging to the Family Harmostomidae Oohur 1912, by W. K. Wesley, Zoology Department, The University, Allahabad. (Communicated by H. R. Mehra.)

29. Note on a Method Determining Refractive Index by Microscope, by A. G. Chowdri, Anglo-Arabic College, Delhi. (Communicated by Dr. D S. Kothari.)

30. Note on Congruent to their Evolutes, by S. M. Kerawala, Mathematics Department, Muslim University, Aligarh. (Communicated by Sir Shah Sulaiman.)

31. On Certain Integrals and Expansions Containing Bessel nnd Legendris Associated Functions, by D. P. Banerji, A. M. College, Mymensingh. (Communicated by Prof. A. C. Banerji.)

32. ~~On Haemo~~pis Indicus N. Sp. A New Arhyncholodellid carnivorus Leech from Kashmir, by M. L. Bhatia, Zoology Department, The University, Lucknow.

33. On the Application of Integral Equation to the Expansion of an Arbitrary Function in a Series of Special Function, by D. P. Banerji, A. M. College, Mymensingh. (Communicated by Prof. A. C. Banerji.)

34. On the Summability of the Conjugate Series of the Derived Fourier Series, by Basdeo Sahai, Agra College, Agra. (Communicated by Prof. Shyama Charan)

35. On the Structure of the so-called Pyloric cæca in a Marine Genus Platycephalus, by M. Rahimullah, Zoology Department, Osmania University, Hyderabad – Deccan. (Communicated by Prof D. R Bhattacharya.)

36. Physiological Study of *Saprolegnia delica* Coker, by R. K. Saksena and K. S. Bhargava, Botany Department, The University, Allahabad.

37. Physiological Studies on the Wheat Plant, Part I—The Effect of Manures on the Total Nitrogen and Amino Acid Nitrogen in *Triticum vulgare* and Soil, by S N. Bhattacharya and Shri Ranjan, Botany Department, The University, Allahabad.

38. Physiological Studies on the Wheat Plant, Part II – The Influence of Molasses on the Nitrification of Soil, by S. N. Bhattacharya and Shri Ranjan, Botany Department, The University, Allahabad.

39. Physiological Studies on the Wheat Plant. Part III—Chlorophyll and Carbohydrate contents of *Triticum vulgare* in relation to manures, by Gopi Narain Dikshit and Shri Ranjan, Botany Department, The University, Allahabad.

40. Physiological Studies on the Wheat Plant, Part IV—The Effect of Manures on the Hydrogen-ion concentration of the roots and leaves of *Triticum vulgare* and of the Soil and the Nitrate Fluctuations in the Soils, by Shri Ranjan and Krishna Gopal Rajvanshi, Botany Department, The University, Allahabad.

41 Preliminary Note on a Collection of Scorpions from Hyderabad (Deccan), together with some remarks on their venoms, by M. Rahimullah, Zoology Department, Osmania University, Hyderabad-Deccan. (Communicated by Prof. D. R. Bhattacharya.)

42. Preliminary Note on X-Ray Mutants in Wheat, by Shri Ranjan, Botany Department, The University, Allahabad.

43. Secondary Nuclei, their Origin and Function, by M. L. Srivastava and D. R. Bhattacharya, Zoology Department, The University, Allahabad

44. Some Colloidal Behaviour of Usar Soils treated with Molasses, by S P. Srivastava, Chemistry Department, The University, Allahabad. (Communicated by Dr. S. Ghosh.)

45. Some Observations on the Cytology of *Saprolegnia delica*, by R. K. Saksena and K. S. Bhargava, Botany Department, The University, Allahabad.

46. Structural Flow in Colloides, by S. Ghosh, ~~Chemistry Department~~, The University, Allahabad.

47. Structure and Development of the Male and Female Gametophytes of ~~*Sesurium*~~ *portulacastrum* Lin., by L. B. Kajale, Botany Department, Hindu University, Benares. (Communicated by Prof. A. C. Joshi.)

48. Studies on the Indian Species of the Genus Cathaemasia with Discussion on the Family Cathaemasidae Fourmann, by W. K. Wesley, Zoology Department, Allahabad University. (Communicated by Dr. H. R. Mehra.)

49. Studies on the Sexual Cycle of the Lizard, *H. Flaviviridis* (Ruppel), by S. K. Dutt, Zoology Department, The University, Allahabad

50. Study of the Volumetric Method for the Estimation of small quantity of Ferrous iron in the Presence of Ethyl Alcohol and Acetaldehyde, by R. C. Talpade, Chemistry Department, Royal Institute of Science, Bombay. (Communicated by Dr. Mata Prashad.)

51. Synthesis of Growth-Promoting Substances by Some Species of the Genus *Pythium*, by R. K. Saksena, Botany Department., The University, Allahabad.

52 Theory of Colour in the basis of Molecular Strain, Part VIII—Colour in relation to Chemical constitution of Organic Nitroso and Isonitroso compounds, by Sikhibhushan Dutt, Chemistry Department, The University, Allahabad.

53. Thermal Ionization of Strontium, by B. N. Srivastava, Physics Department, The University, Allahabad.

54. Time of setting of Barium Malonate Gels at Different Temperatures, by K. N. Mathur, Chemical Laboratory, Royal Institute of Science, Bombay. (Communicated by Dr. Mata Prasad.)

55. Viscosity of Some Sols at their Various Stages of Purity and Dilution, by S. Ghosh and S. M. Ayub, Chemistry Department, The University, Allahabad.